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DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

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THE PROGRESS OF SCIENCE

THE TRANSISTOR'S PROGRESS

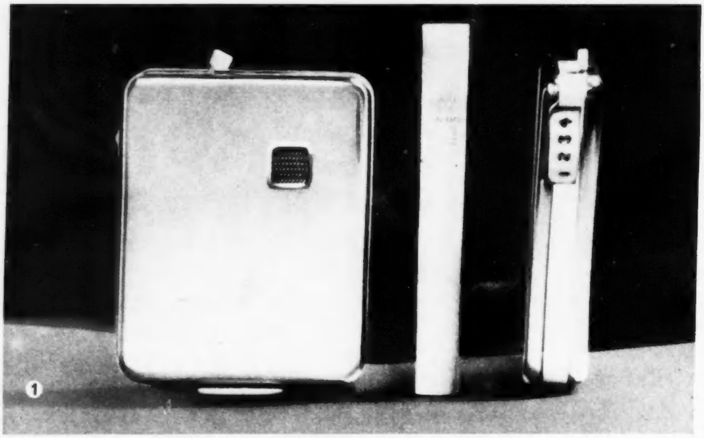
If the dictum that it takes ten years for a new scientific discovery to reach everyday use is true then it will be three years before the transistor achieves that goal. However, the indications are that this remarkable device will be in quantity production within the next twelve months. Already one organisation in Holland is said to be turning out more transistors than the American concern in which this device was invented. The demand for transistors is growing rapidly, and the stage has been reached where one famous British firm of valve manufacturers is completing plans for a large new factory that will concentrate on transistor production.

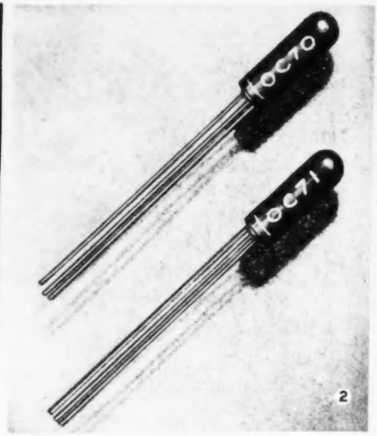
The original device described in 1948 by Brattain and Bardeen (of the Bell Telephone Laboratories) consisted of a small crystal of germanium to which three electrodes were attached. Two were "cat's whiskers", or fine wire points, separated by a very small distance, while the third was a massive plate. Such an arrangement, it was found, would in certain circumstances behave in a manner analogous to the triode valve. Small changes in the potential applied to one of the cat's whiskers produced very large changes in the current flowing between the other whisker and the base. The importance of this effect was immediately appreciated, and intense effort was put into the extension of current theories of the behaviour of electrons in solids in order to explain it. Largely as a result of this theoretical work we now have a whole family of "transistor-like devices"; some retain the cat's whisker, others do not, some have three electrodes, others two or four, and new types are being produced at frequent intervals.

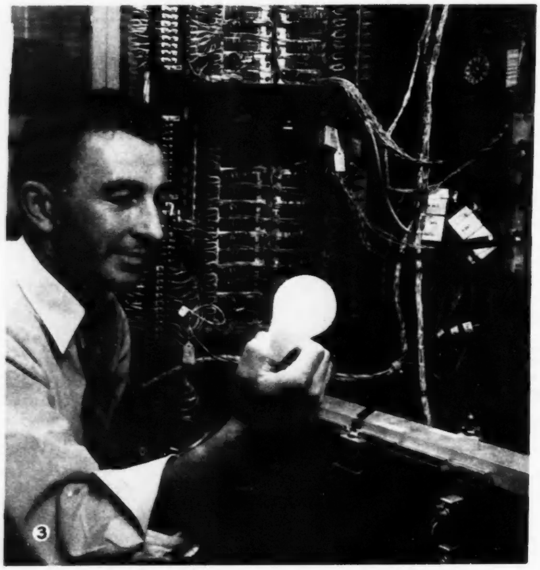
Alongside this tremendous activity in the field of physics there has been a parallel stimulation of the chemists who have been called on to find means of producing what had been considered to be rare or unusual substances, not only in a state of extreme purity, but also in the form of single crystals some centimetres in dimensions. So far, only two substances have been used in commercial transistor production. These are the elements silicon and germanium. The problems involved in the preparation of these elements in suitable form and purity are enormous, and there is a fascinating story in the development of the new techniques that have had to be devised to achieve these results. One "impurity" atom in 10 million of germanium will destroy its usefulness as a transistor. A wide range of little known compounds are being studied as a result of theoretical predictions that they might show the characteristics on which transistor manufacture can be based.

What, one may ask, is all the fuss about? The answer lies in the single phrase: "No heater required." In even the smallest of miniature radio valves it is necessary to heat one or more of the electrodes to a temperature of several hundred degrees Centigrade. To do this, power is required, usually very considerably more power than that which the valve is used to control. The disadvantages which stem from this essential requirement are legion. Two examples may be mentioned. Many of the vast electronic computing machines now developed make use of several thousands of valves. The power dissipated in the heaters of these valves, running into kilowatts, is such as to require elaborate forced cooling of the entire equipment. At the other end of the scale, the short life of the batteries used in "deaf-aids" is due to the power consumed by the heaters in the amplifier valves (which of course are "on" whenever the aid is switched on) and not that dissipated in the earpiece. Apart from considerations of power supply, the life of the valve itself is determined by the gradual deterioration of its heated electrode.

This, then is the promise held out by the transistor: to be able to perform the functions of a valve without the need for any wasteful consumption of power. That this can be done in principle has now been amply demonstrated. Whether it can be done in practice with sufficient reliability and reproducibility of performance (and it must be remembered that the reliability of the valve has been steadily improving for fifty years) we







APPLICATIONS OF THE TRANSISTOR

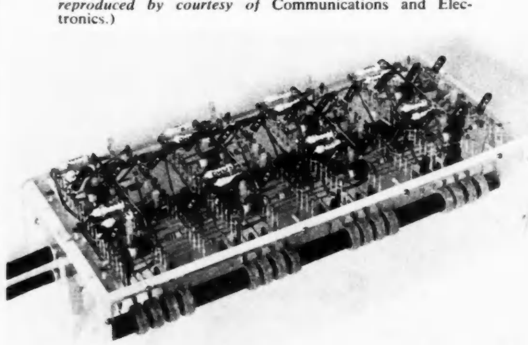
FIG. 1. The Multitone hearing aid's compactness results from the use of transistors (of the OC71 type, shown in FIG. 2), which eliminates the bulky high-tension battery otherwise necessary in hearing aids.

FIG. 3. TRADIC, a digital computer under development at Bell Telephone Laboratories for use in military aircraft, contains nearly 800 transistors. Its power consumption—less than the power used by the 100-watt bulb the engineer is holding—is about a twentieth of that needed by comparable vacuum-tube computers. Here again compactness is a prime consideration; this particular computer cannot take up more than three cubic feet of vital aircraft space. Harwell has a new computer using transistors, which operates a hundred times faster than the vacuum-tube machine which it is replacing. Manchester University has also built a transistor computer.

FIG. 4. The potentialities of transistor amplification are shown in this experimental telephone equipment designed for use in noisy situations. The normal microphone has been replaced by a "close-speaking microphone" which does not respond to background noises. The feeble output of this microphone is brought up to normal level by the tiny transistor amplifier seen in the foreground, which is small enough to be incorporated into an ordinary telephone hand set.

FIG. 5. A shifting register using junction transistors. Shifting registers are used in electronic computers.

(Figs. 2, 4 and 5 are Mullard photographs; Fig. 1 is reproduced by courtesy of Communications and Electronics.*)*



shall know very soon. The types already available in quantity are being used in both the applications mentioned above, and a portable radio set is on the market in America which, using eight transistors, will run for 500 hours—a year of normal use—on four small flash-light cells. By using special mercuric oxide batteries 2500 hours' performance can be obtained.

Transistors cannot, of course, be substituted directly for valves, and there are some types of valve which they will not replace. Equally, there are some transistor applications which could not be achieved using valves. Circuits must be redesigned to take advantage of transistor characteristics and to minimise the effects of their shortcomings, among the most serious of which are their sensitivity to temperature changes, and their inability to handle high frequencies.

READING LIST

The following new books will be found useful by readers requiring further information on transistors:

Transistor—Theory and Applications by Abraham Coblenz and Harry L. Owens. McGraw-Hill, 1955, 311 pp., 42*s*. 6*d*. An excellent introduction to both theory, manufacture and applications.

Transistor Audio Amplifiers by R. F. Shea. Chapman & Hall, 1955, 219 pp., 52*s*. An exhaustive treatment of this field.

Fundamentals of Transistors by L. M. Krugman. Chapman & Hall, 1954, 140 pp., 21*s*. Concerned mainly with transistor circuits.

MODELS AND HYDRAULICS RESEARCH

The work of the Hydraulics Research Station (which is directed by Sir Claude Inglis) continues to be almost the most obviously and consistently practical of all the various lines of research that are pursued by establishments of the DSIR. The number of problems it deals with continues to increase, so does its range of techniques. The earliest post-war tidal scale-model—part of the Forth near Rosyth—was housed at Teddington and had tides laid on by a plunger which operated with almost complete (but unnatural) regularity, whereas the large model of the Thames built years later at the Victoria Dock in London has a correct tidal profile which fits the recorded observations of the Liverpool Tidal Institute and is produced by an electronic mechanism. Now, as its latest report shows, problems for research come not only from authorities in Britain but from far-off parts of the world, and the class of research has gone on from the earlier investigation of silting to the study of coast erosion and fundamental research on such matters as the stability of sand beaches and the movement of cohesionless grains under the influence of moving water. The new universal tool, the radioactive isotope, has been included in the hydraulics researchers' armamentarium. Engineers now come to the Hydraulics Research Station, at last housed on its sizeable estate at Wallingford, for research to be done in advance when new river works or harbours are to be built. The very latest inquiry relates to work undertaken by Sir William Halcrow & Partners in connexion with a proposed new harbour at Tema on the Gold Coast.

In their new home at Wallingford the scientists still build tidal models. At the same time they have a wave channel 185 feet long and 4 feet wide for the investigation of wave problems, especially the effect of wind on wave propagation. There is an area of sand, about a 100 yards by 30 yards, in which the subsoil water-level can be controlled. A new instrument, a free-running rotary flow-meter, made of acrylic resin, has been developed at the Station during the past year. Research has been done on the design of a syphon spillway for the Sudan. Scientists include in their sphere a considerable amount of field work on site.

Models now in active use or being prepared include that of the Thames already mentioned, the Wyre, the Severn Barrage, the Severn at Shrewsbury, Southwold Harbour, Morecambe Bay, Lyttelton Harbour in New Zealand, the Maisemore Barrage on the Severn, the Karnafuli river in East Bengal. Many of these have been "proved", that is to say, shown to be accurate in reproducing in miniature the conditions found in the original, and practical conclusions have been drawn, some of them interim because of the long time over which a model must be used, about what can be done to solve the problems originally set. One example will serve to show what sort of advice these scientists can give after exhaustive experimentation with models and on site.

The Thames model was built for the examination of two main problems: the accumulation of mud in the Mud Reaches—Gallions Reach, Barking Reach, Half-way Reach—in which silting is severe, and the silting of Tilbury Docks. Normally the dredging of the Thames necessitates the dredging every year of some 3 million cubic yards of mud at a cost of about half a million pounds. A few thousand pounds spent on successful research would therefore represent a great economy.

The water in Tilbury Docks is kept at a level a little below that of high water in the river at spring tides (the fortnightly high tides). To preserve this level under all tidal conditions, water has to be pumped in. Water can also go in, with its suspended silt of course, when the locks are opened for the release of ships, for when a ship goes from the dock into the lock it displaces water, which passes back into the dock. When the ship goes from the lock out into the basin or river, the same process puts into the lock a fresh supply of muddy water. Two lockings-out in quick succession could therefore transfer to the dock a substantial quantity of new silt. In order to see if this operation is in fact a cause of silting, the dock records were examined and it was found that two such lockings-out do not occur very often. This source of silt can therefore be disregarded.

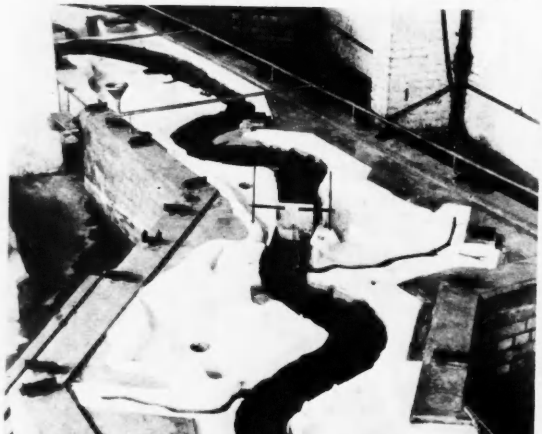
One suggestion made was that the silt went in with the pumped water, and if the time of pumping in relation to high water was changed this transfer of silt could be lessened. Quantitative examination showed, however, that the quantity of silt carried over by the pumps was only a small proportion of the total silt. So this suggestion was not likely to affect the issue enough. The research had to be widened. Sampling surveys of silt and measurements of current were made and records

FIGS. 1-2. The left-hand picture shows an aerial view of Southwold Harbour and the River Blythe; on the right is the harbour model. The ferry service from Walberswick to Southwold (its route is indicated by white broken line) has had to be discontinued because of the intensity of the wave formation in the harbour. The research is designed to discover the causes of these waves and how to lessen their effect so that the ferry service may be resumed.

FIG. 3. The New Zealand authorities approached the Hydraulics Research Station in connexion with plans for protecting the harbour at Port Lyttelton against storms and long ocean waves. The Station built two models in one basin (seen here on the left) to investigate these special problems. This investigation has now been completed, and the basin now holds a model of Tema harbour.

FIG. 4. View of Thames model looking downstream from Barking to Tilbury. The only satisfactory way of reducing flood risk up-river is that of a barrage closed shortly before a predicted sea surge. In the model the barrage is being tried in Long Reach (between Purfleet and Greenhithe).

FIG. 5. The Station's main hall provides a floor area of 300 ft. × 200 ft. for experimental work. The model seen under construction will provide data for the River Severn flood relief scheme at Shrewsbury.



of pumping were examined. A balance-sheet of dredging versus silting was made. At the same time observation showed that there was an important difference between the performance of the dock gates at the two entrances, the New and the Old, for at the Old Entrance the gates swing open under pressure of the high tide whereas at the New Entrance the gates are kept shut by hydraulic rams. In addition the amount of silt at the Old Entrance part of the river is greater than that higher up at the New Entrance. The balance-sheet bore out the suggestion that most of the silt runs into the dock through the Old Entrance, nearly 80% of what is dredged having run in there.

The final recommendation made to the Port of London Authority was the fairly simple one that the level of water inside the docks should be maintained at a higher level, in which case no water could ever run in; it could only run out. A problem of many years has thus been solved in a thoroughly practical way.

So far there has been no such clear-cut conclusion about the Mud Reaches, largely because of the paucity of fundamental information on the formation and behaviour of fluid mud. In one line of attack radioactive tracer—scandium oxide, a gamma-emitter—has been incorporated in glass ground into particles of the same size as the silt particles, and a research boat equipped with Geiger counters is able to trace the movement of these particles. Data of this sort as well as other information are now being collected while experiments are done on the model.

An extra problem, a result of the 1953 flood disaster, has been examined with the help of the model. It has now been demonstrated that even if no flooding had occurred in the estuary the high-water level at London Bridge would have been but about 4 inches higher than it was. This flooding includes that through breaches as well as that spilling over the banks. Flooding by spill alone would reduce the high-water level at Tilbury by about half an inch and in London by about an inch. Further experiments with the model have shown that had the surge at Southend in 1953 been 18 inches higher, that is, if it had coincided perfectly with high water, the increase at Woolwich would have been 27 inches and at London Bridge 20 inches, and if spill-over flooding had then occurred the lowering effected would have been nil at Southend but about 15½ inches at London Bridge, where the water would still have been 4½ inches higher despite the estuarial flooding by spill.

All these experiments combined to show that controlled flooding of the estuarial land, even if it were acceptable, would not be a practical way of preventing flooding higher up. Accordingly, experiments have been made with a barrage in Long Reach (the stretch from Purfleet to Greenhithe) closed only when a surge is predicted. This is found to influence the height of water up-river to a very considerable extent while making a negligible difference to the height down-river. Different types of barrage gate are being tried and the whole investigation continues.

(All the photographs reproduced opposite are Crown Copyright pictures, except for Fig. 1 taken by Photoflight Ltd. of Elstree.)

REFERENCE

Hydraulics Research 1954: Reports of the Hydraulics Research Board and the Director of Hydraulics Research. H.M.S.O., 1955, 5*s*.

SCIENTIFIC RESEARCH IN INDIA

During the war plans were made for a chain of research laboratories to be created in India that would provide the nucleus of a pattern comparable to that of the laboratories of the DSIR in Britain. These plans were not shelved when India achieved self-government, indeed if anything their implementation was accelerated, so that within a period of about five years India brought into being a dozen or so substantial and important laboratories that bear comparison with those existing in the West. One of the reasons why such rapid strides have been made is that the Prime Minister of India, Mr. Nehru, has put all his influence behind the expansion of scientific activities in India.

In a recent lecture to the Royal Society of Arts on the subject of Scientific Research in India, Sir Alfred Egerton explained how the country's research activities have been expanded and described the scale of this expansion.

In this lecture he mentioned the preliminary steps which laid the basis for subsequent developments. There was, for instance, the establishing in 1942 of a Board of Scientific and Industrial Research, which was accompanied by the appointment of Sir Shanti Bhatnagar (whose sudden death in January 1955 removed a great figure from the Indian scientific scene) as Scientific Adviser to the Government of India. A large Industrial Research Fund was created, administered by the Council of Scientific and Industrial Research. By 1942 plans for a National Physical Laboratory and a National Chemical Laboratory had been worked out and had been accepted.

One gets the impression from Sir Alfred's lecture that the movement towards the greater exploitation of science gained very considerable impetus when India became self-governing. To quote his words, "Although much was started before the attainment of independence, it was after 1947 that scientific research got the full recognition and encouragement due to it." In 1948 the Department of Scientific Research was created with Bhatnagar as Director, and in 1951 the further organisational step was taken of creating a Ministry of National Resources and Scientific Research, with Bhatnagar as its Secretary. The plans for the new national laboratories were implemented with great vigour, so that in the five years following independence twelve new laboratories were completed and began work.* Their

* These are: National Physical Laboratory, New Delhi; National Chemical Laboratory, Poona; National Metallurgical Laboratory, Jamshedpur; Fuel Research Institute, Dhanbad; Central Glass and Ceramic Research Institute, Calcutta; Central Food Technological Research Institute, Mysore; Central Drug Research Institute, Lucknow; Central Road Research Institute, New Delhi; Central Electro-Chemical Research Institute, Karaikudi; Central Leather Research Institute, Madras; Central Building Research Institute, Roorkee; Central Salt Research Institute, Bhavagam.

staffs total 3000, of whom about a quarter are scientists. Some have thought that the laboratories are on too large a scale in comparison with the size of the industries of India. At present that may be so, but, as Sir Alfred explained, they are there to help India to industrialise and as industrial expansion occurs they will by no means be out of scale.

As Sir Alfred so righly stressed, the fruitfulness of science is not of money but *of men*. India was lucky to have the benefit of the great services of Bhatnagar. The direction of the fine new laboratories is in good hands too: men such as Sir K. S. Krishnan, F.R.S., who is the first director of the National Physical Laboratory; Prof. G. I. Finch, F.R.S., who went from London's Imperial College of Science and Technology to follow Prof. McBain as head of the National Chemical Laboratory; and Dr. Billig, the Austrian engineer, who is world-famous for his pre-stressed concrete work and is in charge of the Central Building Research Institute.

The big decisions on scientific policy are taken by the governing body of the Council for Scientific and Industrial Research. This has twenty-one members, and its president is the Prime Minister who regularly attends its meetings. If there is a need for co-ordinating the various research activities coming within the Council's sphere of influence, there is also a great need for decentralising the administration of the laboratories as far as possible. Sir Alfred stressed the importance of this problem which has to be given special attention in India, since the distances between the laboratories and the Council's headquarters are large and it is not so easy to bring people together for frequent consultation as it is in England.

Comparatively speaking, very few industrial concerns in India are big enough to have their own research laboratories. This applies in the textile industry, though the total output of all the firms engaged in the industry is very considerable. Research Associations on the British pattern provide a way round the difficulty of financing scientific investigations where the individual industrial units cannot maintain their own research teams. Three research associations have already been formed for textile research.

Sir Alfred Egerton's lecture was largely based on his experiences during a recent visit when he toured the country inspecting laboratories as a member of a committee established for the purpose of reviewing the work of the Council for Scientific and Industrial Research. This committee made recommendations as to how gaps in India's research front should be filled, and in this connexion Sir Alfred told his Royal Society of Arts' audience that India needs to encourage biological work, and said that the committee's report called for special attention to be paid to astronomy and meteorology, to physiology and to the development of the engineering sciences.

JUDGMENT ON ISONIAZID

Just over two years ago (DISCOVERY, February 1953) we reviewed the possibilities of the then new therapeutic agent called isoniazid—isonicotinic acid hydrazide—and its place in the treatment of tuberculosis. Over two years have now passed and seven reports of the Medical Research Council dealing with isoniazid have appeared. One clear fact emerges from them. Isoniazid is an extremely valuable drug—not a wonder drug as so many early reports once prophesied, but something which can take its place alongside the two established anti-tubercular agents, streptomycin and para-aminosalicylic acid (PAS).

It is still true that the drawback of all anti-tuberculosis drugs—the development of drug resistance by the bacillus—occurs, but it is not such a limiting factor in the case of isoniazid as was at one time thought. In many cases it has been found that the resistant bacilli are avirulent. Nevertheless the greatest value of isoniazid lies in its use in combination with the other two agents mentioned above, and the Medical Research Council have been engaged on assessing its value when given in this way.

Their latest report, the seventh, showed that 1 gram of streptomycin by injection and 200 milligrams of isoniazid given by mouth daily was the most effective treatment discovered for avoiding drug resistance. PAS and isoniazid in combination were not so effective. So far, the Medical Research Council has not been able to assess the long-term value of the isoniazid/streptomycin combination and it may well be that PAS/isoniazid/streptomycin may be the combination of choice. Certainly the use of the three in rotation has given encouraging results.

Nevertheless, the search for new anti-tuberculosis drugs must go on. Scientists still pin a good deal of hope on the possibility that an antibiotic may provide the final answer. Already, of course, streptomycin is well established and viomycin has a limited value when streptomycin for some reason or another cannot be given. Usually this is because of bacterial resistance or unpleasant side effects which occur in many patients. Terramycin, one of the newer general-purpose antibiotics with a wide range of activity, has also shown some promise in combination with isoniazid.

Recently, from the United States, has come the news of the isolation of yet a further antibiotic of possible value in the treatment of tuberculosis. This is known as cycloserin which has been put on the market under the trade name of Seromycin.

One other new synthetic product is worthy of mention. Its chemical name is isonicotinamide, and the compound is related to isoniazid. Although it is highly active against the tubercle bacillus, resistance quickly develops. Work with this drug is continuing for the possibility has to be considered that it may prove to have considerable value in combination with other agents.

The battle against tuberculosis is still far from being won. The number of drugs not wholly effective when used separately steadily grows, and it seems reasonably certain that if the ideal drug is not found the objective of this search may be achieved by finding suitable combinations of drugs which do not provide a cure when used by themselves.

RESEARCH BY ROCKETS

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There is something especially fascinating about the study of our own planet. The atmosphere that surrounds us is the source of so much mystery and beauty: the rainbow, the sunset and the blue of the sky, or the aurora with a soft, unnoticed flourescence. It is bombarded by streamers, or the transient meteors which cross the evening sky. These are just a few of the happenings that challenge our understanding and act as incentives to more research.

By day and night, for example, the upper air glows with a soft, unnoticed fluorescence. It is bombarded by silent cosmic rays which end their paths from outer space in violent nuclear collisions high above the earth. There too, gales blow at hundreds of miles an hour and huge electric currents flow to cause magnetic storms, and all the time intense x-rays and ultra-violet light, protons and electrons from the sun bombard the upper air.

Many of these phenomena have a practical importance quite apart from their intrinsic interest. They may affect the weather or radio communication, or they may be important in the future for navigation or defence. So for reasons of pure or applied science there are, throughout the world, many geophysical research stations constantly carrying out experiments, observing and recording.

In the course of a year a vast amount of information becomes available for analysis and scrutiny in the search for a deeper understanding of what is going on around us. But co-operation and co-ordination is by no means easy in such world-wide research and useful work is all too easily wasted. Suppose, for example, that I am interested in the connexion between the aurora and the high-altitude electric currents that flow at the Equator. It is more than likely that I will find that the information I need from Arctic and Equator is not available for the same day in both regions. It may not even be available for the same season. To assist research, therefore, from time to time, so-called "International Years" are held, when research effort is intensified and a special attempt is made to co-ordinate what is going on.

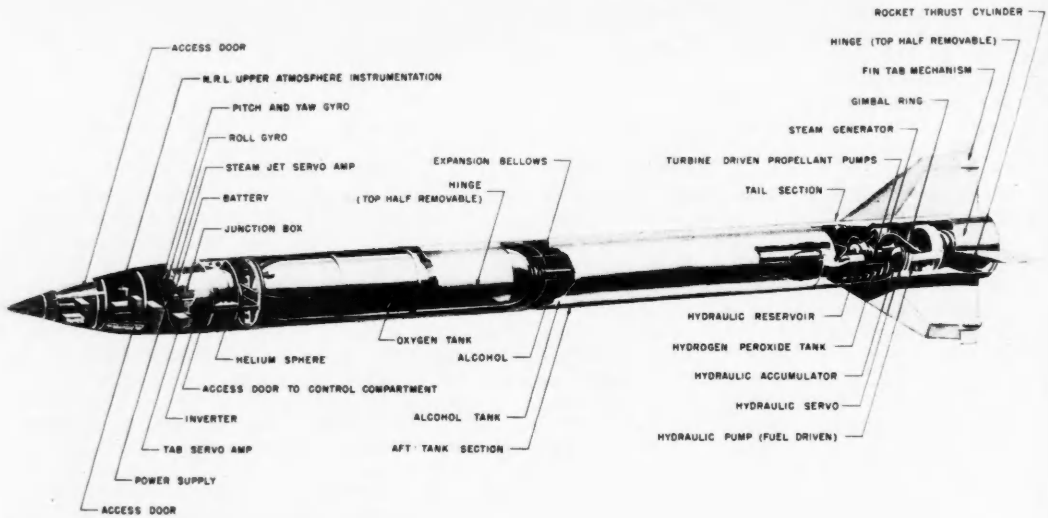
The next geophysical year starts in the summer of 1957 and this time we have a new and very powerful research tool at our disposal—the high-altitude rocket. For the first time the valuable data collected in one of these international years will contain many vitally important direct observations made high above the earth by rockets. In these rockets scientific instruments will be carried to heights of up to 150 miles or more.

Attempts to carry instruments to great heights have been going on ever since the dawn of experimental science. In 1643 the newly invented barometer was carried to the summit of the Puy de Dôme in France to find out about the fall of atmospheric pressure with altitude. Much later the Manchester chemist, John Dalton, found that samples of air from Snowdon and Helvellyn were less rich in oxygen than the air of Manchester. Snowdonia and the Lakes need have no fear for their popularity, however, because we now know that the loss of oxygen was really due to reaction with the vessel in which the samples were taken. Kites were amongst the earliest devices to be used for studying the atmosphere and so were balloons. Indeed balloons are still very important as they can reach a height of 20 miles—about twice that at present attainable by aircraft, and of course they are much cheaper to use than either aircraft or rockets. However, it was with the advent of the high-altitude rocket that the direct study of the upper atmosphere first became possible.

As a projectile the rocket is very old. It was used as a weapon more than seven centuries ago, and as a curiosity it may be much older. But it was with Hitler's sinister secret weapon, the 9-ton V-2, that direct observation of the upper atmosphere first became practicable. The V-2 was an outstanding technical achievement. It was intended for a ground-to-ground range of about 180 miles, and even on this trajectory it carried a ton of high explosive to a height of 60 miles.

With the capture in 1945 of a number of these rockets high-altitude research started in earnest. Since then some sixty-nine V-2's have been launched by the United States Army in the desert of New Mexico, and they have carried more than 20 tons of scientific instruments to heights of up to 130 miles. Indeed one of these vehicles played an important role in setting up the present altitude record. On this occasion it carried on its nose a smaller rocket weighing a third of a ton, which continued on its way after the fuel of the V-2 was spent and reached a height of 250 miles. During its flight important information on the electrical state of the atmosphere was obtained.

The V-2 was an immensely expensive and complicated mechanism. Its jet engine burned liquid oxygen and alcohol at a rate of several tons a minute, and it needed a team of thirty men to launch it. It is doubtful whether it was a sound military proposition, and it certainly was not economic as a peacetime research tool. Other rockets have therefore been developed, principally in the United States. Indeed up to the present virtually all rocket research in the upper atmosphere has been carried out by the Americans. They have developed three types of vehicle—the Aerobee, which lifts 150 lb. of equipment to a height of 80 miles; the Viking, which can reach 160 miles with a similar pay-load; and the Rockoon, so-called because it is launched from a balloon, at heights where the air-drag is very much less than it is at the surface. This greatly increases the peak altitude reached by the vehicle. The Rockoon can carry up to 60 lb. of instruments to heights in excess of 60 miles. More recently the French have developed the Veronique, with a similar performance to the Aerobee. A modified model of the Aerobee designed



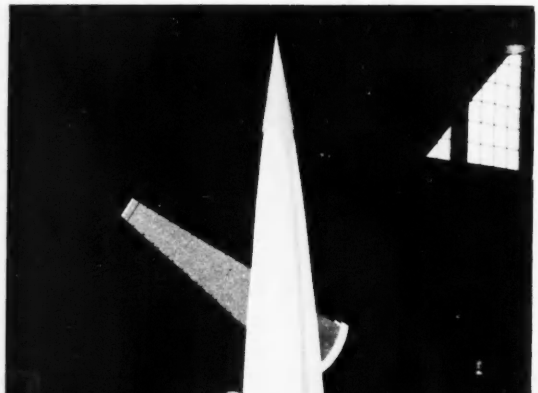


FIG. 1. Cutaway drawing of the Viking rocket. Relatively little space is available for carrying research instruments.

FIG. 2. Aerobee nose-cone fitted with a servo-mechanism (called a biaxial sunseeker) actuated by photo-cells.

for collecting meteorological data was reported (on May 9, 1953) to have attained a height of 123 miles.

As a laboratory, for that is what it is, a rocket is far from ideal. It is cramped. It heats up considerably whilst travelling at velocities several times that of sound, and it gets to a height where high-tension equipment must be pressurised to prevent electric discharges taking place in the very thin air. In addition during the climb the rocket subjects its load of instruments to large accelerations and intense vibrations. After all its fuel is burnt out the vehicle is moving freely in space and instruments that depend for their operation on gravity can only be used if an artificial acceleration field is induced by causing them to rotate. Finally the whole is often utterly destroyed when it crashes to the ground or is broken up in the air to reduce the impact velocity of its parts, by increasing their drag. But perhaps the greatest practical drawback of all is expense. A rocket flight usually last about six minutes, and it is exceptional for any appreciable part of the capital value of the vehicle and its equipment to survive a flight. The Viking costs £100,000 and the Aerobee £10,000. Both these rockets, however, have liquid fuel motors rather like than in the V-2 and it now seems likely that the expense can be very greatly reduced by using solid propellents. Such a system is in principle little more than an engineered version of the rockets let off on Guy Fawkes Night. The Rockoon is like this, and with its balloon costs only about £500.

A rocket flies like an arrow. Whilst it is in the lower atmosphere its fins keep it head-on to its direction of motion and slight irregularities in them give it a slow

roll. This rotation about its axis can be very useful. In observing the sun, for example, it ensures that the side of the rocket containing the instruments periodically faces the sun. At a height of 20 miles the pressure of the air is only one-thousandth of that at sea-level. Above this height the arrow-like stability becomes very small so that at its summit the rocket may be turning over and over in space. To overcome this continual change in the aspect of the rocket some of them have been fitted with stable platforms which are kept facing the sun by a photo-electric cell and servo-mechanism. In another—the Viking—the whole vehicle is stabilised by steam jets during its passage through the thinner parts of the atmosphere.

From what has been said it is clear that it is now possible to carry instruments to very great altitudes. But that is only part of the problem because the information collected must be safely sent back to the ground. Here radio devices are very important, although use is also made of air breaks and much important information has been collected by photographs, magnetic recordings and other means. Radio and photography also play an important part in determining the aspect and altitude of the rocket at each instant of its flight. Radio too, makes it possible to destroy the vehicle if it is found to be off course and pursuing a path that might become a danger to the community.

There is not space here to describe in detail the success that has already marked the use of high-altitude rockets. But I must mention one or two important discoveries. We saw earlier that the sky glows with an unnoticed fluorescence. This air-glow has long been observed at night from the ground but during the day scattered sunlight obscures it. Now to a rocket at an altitude of 25 miles the sky is dark and stars appear even at noon. At least it would be dark were it not for this fluorescence which has been found to have a surprisingly high intensity equal to about 3% of the ground sky light. This flourescence is induced by sunlight, and indeed several other important solar phenomena have been discovered. It has been found, for example, that the sun gives out intense X-rays which fortunately are absorbed by the atmosphere and never reach the ground.

Another discovery concerns the earth's magnetic field. For a long time observations on the variation of the earth's magnetism have shown that large electric currents circulate the globe. But the altitude of these currents was uncertain until rocket measurements revealed that at the Equator many thousands of amperes of electricity flow at a height of 60 miles.

And now what of the future? Consideration is already being given to establishing a satellite laboratory, but before this comes there is still a great deal to be done with present techniques.

Amongst the experiments planned for the future two seem to me to be of special interest. For some years I have been interested in the constitution of the ionised layers of the upper atmosphere—the layers that make long-range radio transmissions possible. We have attempted to simulate in the laboratory some of the conditions prevailing in these regions so as to discover just what charged particles there are in these regions and how many of each type. Now with the aid of measurements made by rockets carrying mass spectrometer probes it should soon be possible to answer this question directly and so to obtain a much better understanding of the various reactions which go on in these layers.

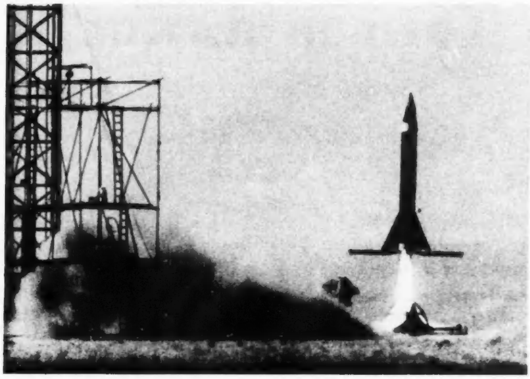


FIG. 3. The take-off of a Veronique rocket.

The second experiment is one proposed by Prof. D. R. Bates of Queen's University, Belfast. From a consideration of photo-chemical processes occurring in the upper atmosphere he has suggested that sodium vapour released at a suitable altitude at night might be strongly excited to emit the characteristic yellow sodium D line. Indeed a few pounds of sodium might produce quite a spectacular effect. Apart from the aesthetic appeal of such a novel form of sodium lighting this experiment, if successful, might lead to much valuable information about winds at these extreme heights.

(This article contains the substance of a recent "Science Survey" talk broadcast by the BBC.)

SELECTED READING LIST

Two Hundred Miles Up by J. G. Vaeth, Ronald Press, New York, 1951. This is a very readable account of the first five years of the American programme for rocket research in the upper atmosphere. Emphasis is on the use of captured V-2 rockets.

Frontier to Space by Eric Burgess, Chapman & Hall, London, 1955. Like the above this is largely a popular introduction to rocket research. It brings the subject up to date, and the last chapter discusses the relevance of current developments to extra-atmospheric rocket research. (Our three illustrations are taken from this book.)

High Altitude Research with Rockets by H. E. Newell, Academic Press, New York, 1953. This is an authoritative and comprehensive account of the state of the science up to 1953; a good introduction for the serious student.

Rocket Exploration of the Upper Atmosphere edited by Boyd, Seaton and Massey, Pergamon Press, London, 1954. This book formed a special supplement to the *Journal of Atmospheric and Terrestrial Physics* and contains papers read at an international conference held at Oxford in 1953.

A review article in *Science Progress* (1954, vol. 167, pp. 435–48) by the author entitled "Rocket Research in the Upper Atmosphere" summarised recent developments in this field.

THE TREND TOWARDS

LONGER RANGE WEATHER FORECASTS

J. S. SAWYER, M.A.

The author of this article has been closely concerned with weather forecasting since joining the Meteorological Office in 1937, and has been engaged on research in connexion with weather forecasting since 1948.

This year the British Meteorological Office celebrates its centenary, and although the Office has not issued forecasts throughout its whole life, nevertheless it is true that scientific weather forecasting is about one hundred years old. Earlier development was impossible because, not until the electric telegraph came into general use, was it possible to obtain weather observations from distant places before they became too old to be of use for forecasting.

Throughout most of this hundred years the basic methods of weather forecasting have remained much the same. Weather observations have been collected and plotted on charts in order to present to the forecaster the distribution of weather at a particular hour. This chart he has analysed to show the distribution of barometric pressure by drawing isobars, or lines joining places with the same barometric pressure, and particular configurations of isobars have been recognised and followed from chart to chart. Weather forecasting is possible firstly because particular patterns of isobars are associated with particular types of weather, and secondly because these patterns move with some regularity. The rainy weather of depressions and the quiet weather of anticyclones are well known, but other isobaric patterns are also associated with characteristic weather.

Although modern weather maps are much more complete and extensive than in the last century, the basic forecasting of the movement of weather systems has remained until recently part simple continuation of their past movement, and part experience of the movement of similar systems in the past.

A NEW THEORY OF PRESSURE CHANGES

In the period from the 1850's to the last world war, there had been many advances in meteorology as a science, but these had been either primarily concerned with the physical processes involved in the weather, or they were of a descriptive character, such as the Norwegian theory of depressions and fronts. No adequate theoretical explanation had been found for the changes of the barometric pressure distribution on the weather map. However, the basis of a theory of pressure changes has recently been developed as a result of the efforts of meteorologists of several nations, and it may lead to revolutionary changes in the techniques of forecasting.

The development of these ideas owes much to the regular availability of observations of wind and temperature in the free atmosphere up to heights of 40,000 or 50,000 feet above the earth's surface. It is now possible to map the air-flow at any level up to 50,000 feet with reasonable precision over most of the northern hemisphere. Such maps are prepared by drawing the contours of the surface at which some particular pressure is reached, for example 500 millibars. These lines are similar to isobars on the surface weather map, and because of the close association between wind and pressure they can be treated as stream lines of the horizontal flow.

Figs. 1 and 2 show two typical charts of the contours of the 500-millibar surface. These represent the flow round the hemisphere at about 18,000 feet above the ground. The flow follows the contour lines and is faster where the lines are more closely packed; the lower heights lie to the left of the flow. It will be seen that a meandering belt of generally westerly winds encircles the hemisphere, the wind being a maximum in middle latitudes. The north and south excursions of the flow, known as ridges and troughs, are common features of the charts, and are referred to as the long waves in the westerlies. A single wave extends over an area as large as the Atlantic and its seaboards; the long waves move only slowly and often change their form little over a period of a few days. This can be seen by comparing Figs. 1 and 2 which show the long waves at times separated by 48 hours. Individual depressions and anticyclones are often steered along the general flow at levels some 10,000 feet or more above the ground, and if the long waves pattern remains stationary, as it frequently does, it may determine the general character of the weather of a week or even longer. Areas in the troughs are notably cold and unsettled, and the areas beneath the ridges quiet and anticyclonic.

The new methods of calculating the changes in the distribution of wind and barometric pressure from one day to the next are a direct application of the theories of fluid motion. The possibility of such calculations was first considered by the late L. F. Richardson in a remarkable book entitled *Weather Prediction by Numerical Processes,* published in 1921. Richardson illustrated his book by a calculation which led to some quite impossible changes in the pressure field; he also concluded that some 64,000 computers would be needed to keep pace with the weather of the world, and probably for these reasons interest in the subject lapsed.

Progress has recently been achieved because, with increasing knowledge of the usual structure of weather disturbances, it has been possible to simplify the problem. Thus, for example, instead of designing the calculation to allow for any observed variation of wind with height above a particular place it has been possible to make use of the fact that through any layer in the troposphere the wind change is usually in the same

FIG. 1.
CONTOURS OF THE 500-MB SURFACE AT 0300 GMT DECEMBER 10, 1950.
(Contours at 400-ft. intervals.)

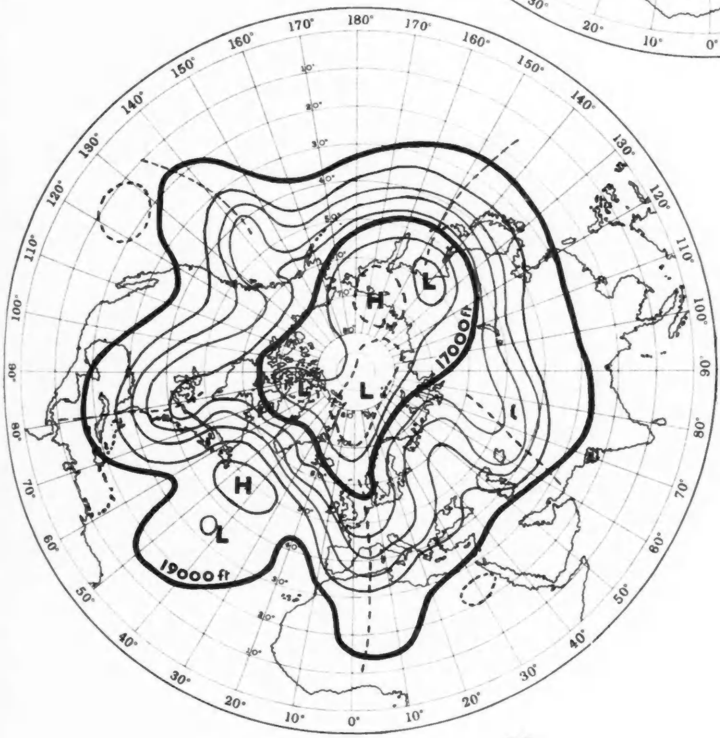
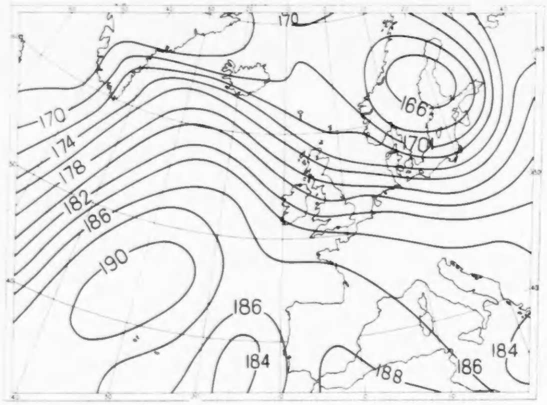


FIG. 2.
CONTOURS OF THE 500-MB SURFACE AT 0300 CMT DECEMBER 12, 1950.
(Contours at 400-ft. intervals.)



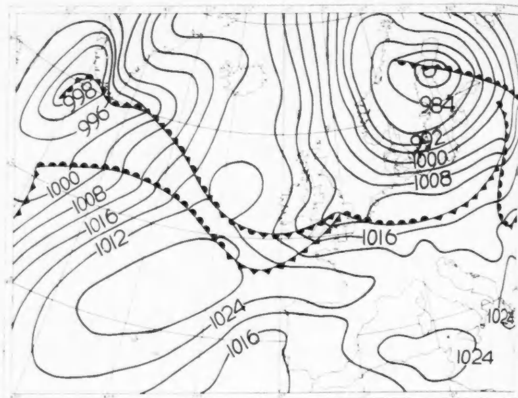
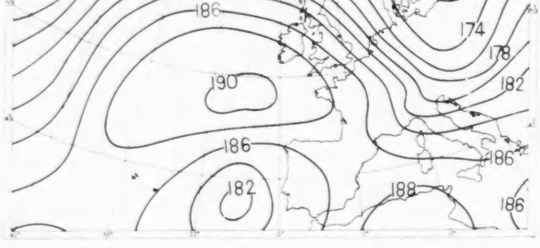


FIG. 3 (*left*). Contours of the 500-millibar surface for afternoon of March 14, 1949, from which calculations were started (units 100's of feet). FIG. 4. Surface isobars for the afternoon of March 14, 1949, from which the calculations were started (units millibars).

FIG. 5 (*left*). Contours of the 500-millibar surface *as observed* on afternoon of March 15, 1949. FIG. 6. Contours of the 500-millibar surface *as calculated* for the same afternoon.



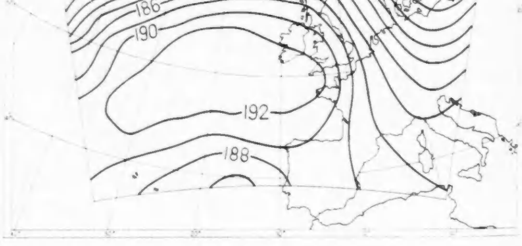


FIG. 7 (*left*). Surface isobars *as observed* on the afternoon of March 15, 1949. FIG. 8. Surface isobars *as computed* for the same afternoon.

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direction. By thus restricting the calculations to the type of atmospheric structure which is usually observed, the calculations have been made manageable. They are still elaborate, and a calculation of the changes in the pressure field expected to occur within a period of 24 hours will involve several million operations of addition, multiplication, etc. Modern electronic computing machines have, however, made such calculations possible, and the time taken to compute the 24-hour changes of the flow at two levels in the atmosphere over an area from Greenland to Italy has been reduced to three hours on electronic computers now operating in Great Britain, and to less than half an hour on the faster machines available in America.

The results of such a calculation are illustrated in Figs. 3–8 by the weather maps for March 14 and 15, 1949. Figs. 3 and 4 show the charts from which the calculations were started. Figs. 5 and 7 which show the 500-millibar contours and sea-level isobars for the afternoon of March 15, 1949, may be compared with Figs. 6 and 8 which are corresponding charts calculated from the weather situation 24 hours earlier. The calculations were carried out long after the event because the method has not yet been sufficiently tested for regular use. There are some large errors in the predicted pressure values, but the shape of the isobars (which is probably more important to the forecaster) is fairly well indicated.

The preparation of a weather forecast by current methods may be divided into two stages. First, the forecaster decides what the weather map will look like later in the forecast period, and he draws the position of the isobars and of the fronts which separate the main air masses of different temperature, as he expects to find them 24 hours later. This he does partly by extending the past movements of the features of the weather map, and partly on the basis of his experience. The second step in preparing the forecast is to decide what weather, what cloud, temperature, etc., will accompany the features of the weather map. This latter step again depends on the forecaster's experience, as well as on a physical understanding of the processes involved.

It is in the first of these stages that the new numerical methods will help the forecaster. Tests conducted so far indicate that forecast charts produced by numerical methods have a standard of accuracy comparable with those produced by the forecaster on the basis of his experience, but they have the virtue of being independent of the personal judgment of any individual. A wide field for research has been opened up here, and there is every hope that the standard of the computed charts may be made even better, whereas improvement of the methods depending on the forecaster's judgment would be difficult.

It is important to realise that the second stage in the forecasting process is as difficult as the first. The new dynamical methods can only give a little help here, because they are able to deal satisfactorily only with motions on the scale of depressions and anticyclones or larger. The pattern of rain areas and cloud systems is usually on a somewhat smaller scale. Cloud and rainfall are always due to the upward motion of the air, but the new numerical methods can only indicate the broader features of the pattern of vertical motion; the vertical movements which take place at fronts between air masses of different origin and the weather disturbances due to local topographical features involve factors which are omitted in order to make the problem of the larger scale motion tractable. Moreover, the detailed distribution of cloud and rain involve aspects of turbulence and cloud physics which are still imperfectly understood.

MEDIUM-RANGE FORECASTING

With the prospect of the numerical calculation of tomorrow's weather chart, it might be thought that one had only to repeat the calculation to produce the chart for the next day and so on into the future. Unfortunately this is unlikely to be so, although workers in Sweden under Prof. C. G. Rossby have continued their calculation to 72 hours and claim a moderate degree of success. The difficulty of extending the forecasts arises because several processes, which have a negligible effect over 24 hours and which are ignored in the computational methods, have a cumulative effect over a longer period. Thus, although over 24 hours the atmospheric system of winds can be regarded as a machine running freely under its own momentum, over a longer period both the slowing effect of friction and the driving energy of the sun's heat must be taken into account. These are processes which are not easily expressed numerically and some time must elapse before they can be incorporated fully into computing methods.

However, some progress has been made towards increasing the period ahead for which forecasts can be issued. This has been possible because of the extension of the network of radio-sonde stations to measure the winds and temperature of the upper air over most of the northern hemisphere. This network has made it possible to study the long waves in the upper westerlies which are illustrated in Figs. 1 and 2. These are on a larger scale than many of the individual depressions and other features of the surface weather map; they move more slowly and on the whole they have a longer life. By extrapolation from past movement, combined with experience and the application of some rather elementary dynamical rules, it is possible to estimate the movement and development of the long waves over two or three days. This is really an extension of the established methods of forecasting to upper air disturbances on the grandest scale, and it provides some indication of the weather type three or four days ahead. It is not possible to give much detail in such forecasts because the individual depressions and fronts which are to bring the rain periods may not yet have appeared on the weather chart when the forecast is issued, and the actual time of their formation may be affected by small and almost accidental influences. Knowledge of the probable long waves pattern enables the general track of weather disturbances to be estimated, but not the time at which they will reach a given point. Thus it may be possible to indicate whether the weather three days ahead will be dry or changeable, but it will not be possible to

decide whether the rain will fall in the morning or some other time of the day or night or to indicate the precise limits of the rain area.

LONG-RANGE WEATHER FORECASTING

But what of weather forecasting for longer periods?—for periods of ten days, a month or even a season? Such long-range forecasting has always presented a challenge to the professional meteorologist. Even to know that a particular month would be generally cold or wet would be valuable for many purposes, and the stimulus to the search for a successful method of long-range forecasting is great.

At the present time there is no widely accepted method of long-range forecasting. Certain meteorological services regularly prepare long-range forecasts, notably those of the United States, Russia, Germany and India, but the methods followed in these countries differ widely. No high degree of success is claimed, and indeed it has yet to be demonstrated convincingly that the results are significantly better than could be expected by simple guessing.

The methods which are employed in forecasting for one to four days ahead cannot be extended further into the future because they depend essentially on the movements of the atmosphere continuing under the momentum of the existing winds. Over a period of five to ten days nearly all the energy of the winds would be destroyed by friction with the earth, were it not renewed by energy which the atmosphere derives from operating as a heat engine, absorbing heat at low levels in low latitudes and disposing of heat by radiation to space at higher levels in higher latitudes. Nevertheless the weather does appear to have moods which last for weeks, or even a month or more, and a whole season may be characterised by unusual dryness or cold.

Thinking of the atmosphere as a heat engine, it is reasonable to seek a basis for long-range forecasting in the variations in the heat supply which drives the atmospheric engine. Ultimately the energy of the weather is derived from the sun, and it is natural to attempt to relate long period variations in weather to the variations in the output of energy from the sun. The total energy reaching the earth is, however, difficult to measure because of absorption by the atmosphere, and, despite extensive work by Dr. C. G. Abbot and others of the Smithsonian Institution, the measured fluctuations are still regarded by some meteorologists as unreliable, and evidence for a connexion with observed weather changes is far from convincing. Meteorologists have not left the matter there, and have considered that variations in a particular type or wavelength of the solar emissions might have an effect on the weather; variations in sunspots, solar flares, and the sun's ultraviolet have all been compared with records of weather changes, but although there is some evidence of an eleven-year cycle in certain weather elements which may be connected with the sunspot cycle, none of these solar influences hold much hope as a basis for long-range weather forecasting—even if the problem of predicting the solar variations were much simpler than predicting the weather!

Most of the energy which drives the atmosphere is not received direct from the sun, but goes first to heat the underlying land or ocean, or to evaporate water from the sea or vegetation. The supply of heat to the atmosphere may thus be greatly influenced by any unusual condition of the ground or ocean beneath. Some such anomalies of temperature of the ground or ocean may persist for several weeks—they may arise from abnormalities in ocean currents, unusual distributions of polar ice, or extensive snow cover overland. So far it has been possible to demonstrate only very slight connexions between such ground conditions and subsequent weather, but the geographical complexity is great and the field for search is almost limitless, so that there may well be significant relations as yet undiscovered.

Most of the surface conditions which might influence the weather are themselves the result of preceding weather. Thus it is not impossible that relations may exist between the weather sequence at one period, and the weather type some weeks or even months later, even though the inertia of the atmospheric movements would have been insufficient to keep the atmosphere going over so long a period. It is on a belief in the existence of such relationships that most current methods of long-range forecasting are based.

The Russian meteorological service was, perhaps, the first to devote much attention to the problem of long-range forecasting and their methods are largely an extension of day-to-day forecasting methods, being based primarily on experience of weather sequences over long periods. Particular attention is paid to the tracks of the main anticyclones across Russia. An interesting idea is that of "natural seasons"—the year is divided into several seasons which it is believed are particularly likely to be dominated by a single weather type, so that if the type can be recognised at the beginning of the season, the general character of the season can be forecast.

The American experiment is based upon charts of the mean contours of the 700-millibar surface over 30-day periods. These represent the average airflow at about 10,000 feet above sea-level over 30 days. Such charts show distinct differences from one month to another depending particularly upon the positions most frequently assumed by the long waves during the month and their intensities. Experience of the sequence of such charts provides a rough means of estimating the appearance of the mean chart for the following 30 days, and a forecast of the general character of the rainfall and temperature—as above or below normal, much above or much below—is made from the known relations of the weather to the flow patterns aloft. The persistence of anomalies of the flow pattern are an important factor leading to the forecast chart and are probably responsible for a large part of the rather meagre success claimed for the method.

Purely empirical is the method used for many years in India to estimate the rainfall of the monsoon and

the winter rains in the north of India. It is based on a search for correlations between rainfall, temperature and pressure in preceding seasons all over the world and subsequent rainfall in India. Observations for the preceding seasons from as far away as the Pacific and South America are used, although the explanation of the relations is not known. Modest success is claimed.

Various other techniques have been used for long-range forecasting. In particular attempts have been made to find periodicities in the records of temperature and pressure, but the number of periods which have been found is nearly as large as the number of investigators, and the oscillations are apt to disappear or change phase as soon as they are used for forecasting.

Thus long-range forecasting remains a challenge to scientists. It is impossible to predict whether a really profitable degree of success will ever be achieved, but the prize is so great that the search must go on. The atmosphere is so complex and the inter-relations between the energy of the oceans, the atmosphere, the ground and the sun so complicated that it seems unlikely that theoretical argument alone can ever trace a direct path between cause and effect over periods of weeks or months. Probably the greatest hope is that with increasing understanding of the large-scale circulation of the atmosphere sufficient physical insight into the processes at work will be obtained to suggest relationships which can be explored and refined by modern statistical techniques and machine methods of handling the vast masses of available data.

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A NEW SOURCE OF RESERPINE

New sources of reserpine, the drug used for treating high blood pressure and hypertension (see DISCOVERY, August 1954, p. 310), are now being widely sought and from Australia comes the news that the tree known as "bitter bark" has been found to contain substantial amounts of it. This tree (*Alstonia constricta*) grows in Queensland and New South Wales to a height of 10–30 feet and is a member of the Apocynaceae, the family to which belongs *Rauwolfia serpentina*, the Indian plant from which reserpine was first prepared.

The discovery was made by officers of Australia's Commonwealth Scientific and Industrial Research Organisation during studies into the pharmaceutical value of Australian plants. According to an official statement to the Australian Parliament, the discovery is expected to be of great value to the Commonwealth both in making the drug available in greater quantities and more cheaply in Australia, and in helping to overcome a shortage of the drug throughout the world. The value of the *Rauwolfia* industry to the United States was estimated at 50 million dollars for the year 1954. Reserpine is at present selling retail in tablet form at a price equivalent to something like £30 to £40 per gram of the alkaloid.

The statement said that the chief source of the reserpine has been India. However, by reason of domestic Indian needs, the export of the roots of the tree from which the drug is extracted has been banned. In consequence other sources in such places as Burma, Thailand and Indonesia are being investigated. Pharmaceutical firms are spending much time and money in their search for better sources of supply—including Central America.

At present natural sources of the drug have to be relied upon because reserpine has not been prepared synthetically—and its structural complexity is such that it is unlikely that it can be produced synthetically on a basis competitive with the natural product.

The Australian discovery was made by the CSIRO Division of Industrial Chemistry. It is believed that *Alstonia constricta* is a source of the alkaloid reserpine of a quality comparable with—if not superior to—any other sources. Biological tests in the CSIRO Division of Animal Health and Production have not so far revealed any difference between reserpine from the Australian source and from commercial preparations based on the Indian source. The Division of Plant Industry of CSIRO confirms that the tree is sufficiently abundant to provide commercial quantities of reserpine. At least two firms are actively looking into the prospects at present.

Continued from p. 247

THE SEARCH FOR TECHNICAL INFORMATION

A. G. KAY

The advance of science and technology has brought about so vast an accumulation of facts that the task of finding specific details on specific subjects can look forbidding. But given a modicum of "know-how" the search for technical information becomes considerably easier. Below we print the second part of the article by Mr. Kay, a Patents and Intelligence Officer of a large industrial organisation, in which he gives hints that will help readers to solve their own technical information problems. Here he is concerned with the tracking down of data published in periodicals and patents, with the importance of abstracts, and with the services provided by specialist libraries. The first part of the article, which we published last month, gave detailed information about key reference books covering physics, chemistry and engineering, and about the use of general reference books and directories; the concluding section was devoted to scientific and technical information contained in Government publications, and it gave some useful advice about the services the Stationery Office offers.

PERIODICALS: THE INDISPENSABILITY OF ABSTRACTS

To the scientist and the technologist the most important source of information is undoubtedly periodical literature—magazine, journals, bulletins, proceedings and so on. In 1950 about 50,000 titles were published throughout the world on scientific and technical subjects alone—this means about 3 million articles and papers a year. That their numbers continue to increase and that there seems to be no limit is a reflection of the interest taken in them and, to some extent, of the value they seem to be.

This huge figure of journals and articles published is at once the joy and despair of those who look for information. On the one hand there is the feeling that out of all this vast and accumulated literature there must exist *somewhere* the particular bit required; on the other hand that bit might be anywhere within the mountain and the search for it may be a time-consuming and quite formidable task.

The search for a paper in a periodical really consists of two parts—the first in finding what journal and what particular issue of that journal carried that paper; the second in finding out what library keeps that journal and in borrowing it.* Usually the first part is the harder.

Most of the material published in these thousands of journals is abstracted somewhere. That is, the information is condensed, and in its condensed form it appears in a separate journal or part of a journal devoted to the publication of such abstracts. The Royal Society issued in 1949 a most handy booklet (costing half a crown) entitled *A List of Periodicals and Bulletins Containing Abstracts Published in Great Britain*. This contains exactly what the title says. In one part of the booklet you can find the titles of the abstract journals divided roughly under such subject headings as Agriculture and Botany, Biology, Chemistry, Medicine, Miscellaneous Industries, etc. In another part of the booklet the titles of the journals—about 300 in all—are listed alphabetically with notes for each one giving a fairly detailed account of the subjects covered, the publishers, price, etc. To give an example, under the title of *The Analyst* appears the following list of subjects on which abstracts are likely to be given: Food and drugs, biochemistry, bacteriology, water analysis, agriculture, organic and inorganic chemistry, microchemistry, physical methods and apparatus. These abstracts, however, are now divorced from *The Analyst* and are published separately in a journal with the title of *Analytical Abstracts*.

This is a start, at any rate, and once you have decided under exactly what headings your required information is likely to be found you can then find the abstract journal which is most suitable to your needs, consult the indexes for each year, and the rest is a matter of wading through the various abstracts to which you are referred to find the right ones. Having found what sounds to be a promising abstract, or series of them, it is then necessary to note exactly the details given about the journal in which the full article appeared. You are now in a position to find the original journal and your article. Before leaving this point, however, I must make clear that this Royal Society publication on abstract journals is concerned only with British journals and is also now rather out of date.

There are many abstracting journals published outside this country. The American *Chemical Abstracts* is an outstanding example which covers a very wide field—in fact, just about everything which is related to chemistry appearing in several thousands of journals published all over the world. *Engineering Index* is another nearly as useful on the engineering side. Unfortunately, I know of no publication giving a complete world-wide list of abstracting journals but, again, an inspection of the catalogues of a good reference library and a word with the librarian will help one out of most of these difficulties.

While it is true that not everything published in every technical or semi-technical journal is abstracted I think it is fairly certain that very little escapes altogether the combined net of all the abstracting services. What

* A book that shows which libraries hold copies of specific scientific journals is *World List of Scientific Periodicals* (1952); this reference work is available in most libraries. Next month Butterworth's Scientific Publications bring out the first volume of *The British Union-Catalogue of Periodicals* listing British library holdings of *all* journals (including scientific), and this catalogue will be completed in 1957.

doesn't appear in an abstracting journal with a wide coverage, such as *Chemical Abstracts*, may very well appear in a smaller, more specialised service such as *Fuel Abstracts*.

Having found the title and issue of the journal which contains the information you want, the question now is to locate a copy of it. For this country the best place without any doubt is in *The World List of Scientific Periodicals*. This book is just about indispensable to librarians concerned with technical matters and will almost certainly be found in every reference library—it will be of immense help to anyone trying to assist himself. In it are published in alphabetical order some 50,000 titles of periodicals published in all parts of the world and, in a separate section, proceedings of international congresses; against each title is given the names of the libraries *in Britain* that hold the journal and a note on how far back each run goes. 247 libraries in the British Isles are covered, taking into account not merely the large public libraries of London and the provinces but those also of institutions such as the Geological Society and the Royal College of Surgeons; in addition some of the more private libraries of industrial companies such as Imperial Chemical Industries and Distillers Company have been included. Once your journal has been located at a particular library you may then apply for it yourself, if that would be appropriate, or obtain it through the librarian of your local reference library.

Some libraries are unwilling to lend copies of their material for a variety of reasons: borrowing may be restricted to members if it is an institutional library; journals may be regarded as irreplaceable or too valuable to lend, or there may be a great demand for some issues. In these cases it may be possible to call personally at the library. In the case, say, of a learned society where the use of the library is restricted to members, very probably the librarian will stretch a point in a genuine instance to permit of a personal visit.

There is always the possibility of photo-copying if the original cannot be borrowed or consulted. Many of the more important libraries have photo-copying facilities nowadays, and at the cost of usually about a shilling a page a photographic copy of the article may be obtained. This may involve waiting some days or even occasionally a couple of weeks, as the photo-copying services in some of the public libraries are not, it seems, regarded as an important enough part of the regular services to take more than second or third place to the apparently more urgent daily routine. It is necessary, by the way, when applying for a photo-copy to indicate that the copy required is for genuine student or research purposes.

THE SCIENCE LIBRARY

The Science Library in London published in 1953 a list of current periodicals available there; this contains about 8000 titles and is obtainable at any branch of H.M.S.O. for 7*s.* 6*d.* There is also a scheme for borrowing material and obtaining photo-copies on demand from the Science Library but this scheme is confined to recognised institutes and organisations (such as the research departments of industrial companies) where scientific work is being carried out. The reading room of the Science Library is available to those wishing to study or carry out literary research.

There is another service carried out by the Science Library which should be better known. Where it is desired to survey the literature on a particular topic, it is first necessary to get together a list of references relating to that topic—in other words, to compile a bibliography. This can sometimes be a long and difficult job; it is a job, however, which will be undertaken on request by the staff of the Science Library. I believe there is no charge made for this valuable assistance.

BIBLIOGRAPHIES

The compilation of bibliographies can be given an excellent start by the study of the various annual reviews issued by different bodies. There are quite a few of these: on textiles, on chemistry, on biology and so on. Each surveys all the important developments in the field for the year, discussing under different headings and giving reference to a great number of papers. The annual surveys prepared by some journals—*Industrial and Engineering Chemistry* is a good example—serve the same purpose on more specialised subjects.

PATENT LITERATURE

A source of information often neglected by scientific and technical personnel is patents literature. While the filing and prosecution of patents are matters which are better left in the hands of a skilled agent, patent literature, properly scrutinised, can provide a wide survey of trends and developments in aspects of applied technology which is unsurpassed. Many of the abstracting journals already discussed do include patents within their purviews but not only can no journal be exhaustive even within its own subject but the British Patent Office itself provides a type of abstracting journal of all British patents. This has the advantage of being in classified sections so that patents on a single subject can be traced fairly readily as far back as 1855 and even earlier. There have been alterations in the actual classification over the years, but generally speaking patents are considered to fall into one of 40 groups of allied subjects and these groups are further subdivided to form a total of 146 classes. These embrace the whole field of invention from plastics to piezo-electric crystals, from mudguards to manure distributors, from egg-openers to explosives. Abridgments—or if you prefer the term, abstracts—often with illustrations, of every patent issued in this country are published in the appropriate class and group in periodically issued volumes each provided with an index. From these you can make up a list of the patents on the subject that interests you, and then proceed to the reading of the full specifications themselves. The main reference libraries throughout the country maintain an up-to-date set of these abridgment volumes and

have a complete holding of all British patent specifications.

The Patent Office has recently instituted a "Fifty-year Subject-matter Service". For a fee of half a guinea a list will be supplied by the Patent Office of all the numbers of the British patent specifications published in the last fifty years on a single subject. The scope of each subject is limited to the Patent Office Classification Mark (these are subdivisions of the Class Numbers). At the moment this service is confined to just over 30 classes but it will eventually be extended to the whole 146 classes. Such a service is invaluable as it not only saves hours of tedious searching but it is complete within each Class Mark. There is still the necessity, of course, to study the specifications listed, but one is saved the preliminary donkey-work; even if you do not require to go back fifty years, for the small fee involved there is little lost in getting the complete list and neglecting everything before a given date. The Classification Key to enable you to specify the exact list you want is also available in the public reference libraries.

Before leaving the matter of patents, I think it is worth mentioning that those libraries which house the British specifications usually keep also American specifications and although no classified abridgments are available for these, U.S. patents can usually be traced by a combined search of the *U.S. Patent Office Index* and the *U.S. Patent Office Gazette*. The *Index* is published yearly and lists the inventors' names and subject-matter of patents; the *Gazette*, which is published weekly, gives abstracts in number order of all U.S. patents issued. One word of warning here, though. The British abridgments are fairly easy to read even by a person without any knowledge of patents and patent jargon; the bulk of the American ones are usually just a recital of the first claim of the patent, and more often than not that is unintelligible without intensive study, and even then one needs some initial knowledge of what the patent is about.

The Patent Office has a very fine library of technical literature of every description and is open to the public. Borrowing is not permitted but photo-copies of the material in the library can be obtained at about a shilling a page. Any British patent specifications can be consulted and, of course, purchased; the patent specifications of many other countries are also filed there.

SPECIAL LIBRARIES

Special libraries, that is, libraries concerned with a comparatively narrow field of interest, are very much on the increase. The majority of these libraries have been set up to cater for the needs of industrial companies and undertakings, government departments, research associations and so on. For a good number of quite justifiable reasons there is a reluctance on the part of those who run these libraries to throw them open to the public in general. There is, though, an excellent spirit of co-operation between the libraries and the public libraries as well as an understanding of the needs and difficulties of the student. Many of these special libraries are prepared to lend or to photo-copy material at the request of a recognised library on behalf of a genuine seeker after information and, provided requests are not too frequent, assistance and facilities would not be refused to the individual making inquiries on his own.

Sometimes, of course, nothing in the way of published information can be found when an out-of-the-way question arises. In this connexion the *Aslib Directory*, published in 1928 and woefully out of date, is of some assistance. This Directory lists a large number of subjects (not by any means all technical) and suggests for each one where information might be obtained, where there is a library or a collection of exhibits. I understand that a new edition of the Directory is now in hand. Meanwhile, Aslib has put out a series of publications giving sources of reference in Great Britain on various technical subjects; the four available just now are on the paper industry (2*s*. 6*d*.), agriculture (16*s*.), food and beverages (12*s*. 6*d*.) and on textiles (12*s*. 6*d*.). Also available is a small handbook published in 1947—*British Sources of Reference and Information: a guide to societies, works of reference and libraries*; the price is 6*s*.

Even though the *Aslib Directory* is so out of date the conception of it does point to an obvious moral—if all else fails, go to the fountainhead. By that I mean that if there is a query on, for instance, knitting machines, and no published information can be found anywhere, it is not unlikely that manufacturers of knitting machines or actual fabric knitters or one of the textile research associations may be able to give the answer.

I am only too aware of my many omissions in this brief guide; hard on my heels while writing it has been the necessity of including one thing only to the exclusion of another. I can only hope to have given to the uninitiated a general picture of how information can be tracked down with a few details here and there pin-pointed for guidance. I do believe, however, that a little intelligence and the use of common sense should enable one to use that picture to carry out a great deal of literary or factual research either alone or with only little help from the specialist. Because he, and he alone, knows *exactly* what he wants, the man who requires the information is often the best person to look for it and I cannot see that there is any good reason why he should not do so himself—and have pleasure in the doing of it.

* * *

For the convenience of readers the addresses of the following institutions mentioned in the article are appended:

SCIENCE LIBRARY. Imperial Institute Road, London, S.W.7.

PATENT OFFICE. Southampton Buildings, Chancery Lane, London, W.C.2.

ASLIB. 4 Palace Gate, London, W.8.

THE WORK OF THE NATIONAL RESEARCH DEVELOPMENT CORPORATION

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(Industrial Manager) (Technical Manager)

The NRDC is a public Corporation set up by the Board of Trade under the Development of Inventions Acts of 1948 and 1954. These lay down a framework within which the Corporation is free to operate as it thinks fit in the discharge of its functions to develop and exploit, in the public interest, inventions resulting from research which has been carried out either in whole or in part out of public funds, or other research which is not being sufficiently developed or exploited.

The finance required for its operation is provided by the Board of Trade in the form of loans, the outstanding amount of which must not exceed £5 million at any one time. The Corporation, operating in the public interest, tries to conduct its affairs so that, in the long term, it will cover its costs, build up a reserve and, in due course, pay back the Board of Trade's advances; it must therefore aim to make a profit on its ventures.

The Corporation possesses no research, development or production establishments of its own and has carried out all its practical activities extramurally. The NRDC must not engage in general research as such, thus it is precluded from financing research in the way say that the University Grants Committee, the Medical Research Council or Nuffield Foundation do. Under the 1954 Act it can, however, with the approval of the Lord President and the Board of Trade, assist financially specific applied research projects the continuation of which seems likely to lead to an invention or the satisfying of a specific practical requirement brought to its knowledge.

FILLING GAPS IN DEVELOPMENT

It must not, except under special circumstances and with permission of the Board of Trade, engage directly in commercial production and distribution. These activities are normally undertaken by its licensees who, special circumstances apart, must be persons "engaged in the industry concerned". Between these two limits it can do practically anything to fill any gap in the development of inventions from the laboratory stage to the point at which they can be used industrially.

The public inventions it receives fall into two main categories; those wholly financed by the Government at its various research establishments, such as those of the Ministry of Supply, Admiralty, Department of Scientific and Industrial Research, and Agricultural and Medical Research Councils; and those from organisations which possess an independent status but receive some financial support from public funds, such as the co-operative research associations, universities, medical schools and agricultural colleges.

For Government inventions as such, a Treasury directive requires that any patent and associated rights shall be automatically assigned to the NRDC. As regards the Government grant-aided but independent sources of inventions, NRDC tenders its good offices to the inventors to aid the development and exploitation of their research results, on a mutually agreed basis. This normally involves an assignment of the rights to the NRDC on the basis of a fair division of the revenues between the Corporation and the inventing source. An increasing proportion of the Corporation's portfolio of inventions now derives from such public sources. As, however, such inventions are usually of longer-term nature, their state of development and exploitation is on the whole less advanced than is that of the Government-owned ones.

As already remarked, the Corporation has to operate "in the public interest". This is assumed to apply to all inventions in which an element of public money has been involved, but as regards the private inventions—whether submitted by firms or individuals—the criterion of public interest must be applied to each case. It is not the Corporation's business to deal with "gadgets"—commercial consumer goods or products with no serious technological merit which private industry or finance is best fitted to handle. On the other hand, if the development of and use of an invention is frustrated through lack of money, or facilities for further development or exploitation, and it is thought by the NRDC that if successful its use would lower costs or improve the general efficiency of industry, or otherwise meet a public need, the Corporation might well decide that it would be in the public interest to give such invention its support.

The technological range of inventions handled by the NRDC stretches from heavy and mechanical engineering at one end of the scale, through electronics and scientific instruments to chemical engineering projects, fine chemicals, pharmaceuticals and biological products at the other. Atomic Energy, Defence and Jet Propulsion inventions are outside its scope.

Some inventions reach the NRDC in a fairly complete stage, practical research results having been obtained and a patent application already filed. Others, however, may still be in a very early condition; some perhaps may have scarcely been taken beyond the scientific discovery stage and may not yet be ripe for patent protection.

Development, when required, involves a period of close technical progressing which may well take several years (five years is by no means excessive), and which may well require substantial expenditure by the NRDC. Each development project has to be treated on its own merits, and it is difficult to lay down hard-and-fast rules. For some, pilot plant work or machinery experimentation and design is required; for others, clinical trials or other extended tests under varied conditions. Each

TABLE I. PATENTS AND PATENT APPLICATIONS COMMUNICATED TO NRDC

	Submissions					*Accepted*				
	1950–51	*1951–52*	*1952–53*	*1953–54*	*Total*	*1950–51*	*1951–52*	*1952–53*	*1953–54*	*Total*
Government Departments and Research Councils	1222	491	273	268	2254	837	414	185	315	1751
Universities, Research Associations and Charitable Organisations	118	64	55	61	298	43	26	61	52	182
Private Sector	942	472	364	335	2113	17	5	11	8	41
Total	2282	1027	692	664	4665	897	445	257	375	1974

SUMMARY	*Accepted*	*Not Accepted*	*Total*
Public Sector	1933	619*	2552
Private Sector	41	2072	2113

* Including "pipe-line" cases for acceptance in 1954–55.

major development is carried out at some stage in co-operation with industry.

The NRDC is at present dealing with more than twenty development projects distributed fairly evenly between Government departments, universities and private sources. It has first to ensure an adequate patent position at home and abroad, then sometimes to organise a "combined development operation" with a research establishment, or to place a development contract with an appropriate laboratory, industrial consultant or firm. In several cases it has participated in a "joint venture" with industry on development finance as experience has shown that promising novel ideas tend "not to be sufficiently developed and exploited" not so much because the spirit of willingness is lacking but because no spare venture capital is available—in particular for taking a scheme beyond the pilot plant or prototype stage to what might be called the "pre-production stage".

The Corporation's latest Annual Report (for 1953–54), which summarises the first five years of the Corporation's work, brings out certain interesting points in relation to the original hopes and expectations for the Corporation and how they have been fulfilled to date.

The original basis of the Corporation's creation was threefold. First, those concerned with the administration of public services felt that a single organisation was needed to deal with the industrial property in publicly-owned patents, the responsibility for which had previously been left with the individual originating ministries. This requirement has largely been met, as will be seen from the statistics set out in Table I. The Corporation's patent rights are beginning to earn revenue from commercial exploitation which should rise slowly but steadily with the years. In the second place, there were men of science who were not entirely satisfied with the liaison which existed between centres of learning and research on the one hand and industry on the other, and who believed that the existence of a public body which could assume this responsibility would comply with a real need and enable science to be applied more decisively to industry and agriculture and at an accelerated rate. Although the NRDC has to date achieved useful results here they have been on a relatively modest scale. Moreover, the rate at which the results of research can be introduced into industry depends not only upon the consciousness in industry of the benefits which can accrue by their adoption but also on a number of economic factors such as the availability of capital for development and production purposes, and the general state of the market.

Thirdly, it was believed in some quarters that full exploitation of the inventive talent of the nation was in part frustrated by lack of support for inventors, particularly amateur inventors without industrial connexions. The Corporation's experience to date has in fact failed to confirm that a multiplicity of meritorious private inventors stands in need of public assistance. Today the isolated private individual rarely appears to be able to make any serious contribution to the advancement of medicine, science or technology. Nevertheless one or two inventions from the private sector have received support each year and it is hoped that the work involved in assessing their merit, together with the money expended on their development, will prove justified in years to come.

SOME NRDC PROJECTS

It would be appropriate now to turn to some of the specific development projects which the Corporation is sponsoring.

Electronic Computers. Of the Corporation's total expenditure to date (approximately £1 million) over £300,000 has been devoted to the computer project, which comprises over 160 British patents and applications, and many more abroad.

Readers of DISCOVERY will be familiar with the general applicability of electronic computers which may well bring about vast changes in industry and the community generally through their impact on automatic production, store and large office accounting and

(*Above*) The computer project of the National Research Development Corporation has been on an ambitious scale. This photo shows one of the computers resulting from this project and produced by Ferranti. (*Courtesy, Ministry of Supply.*) (*Below*) The Packman Potato Harvester. A number of these machines will be in action during this year's harvest.

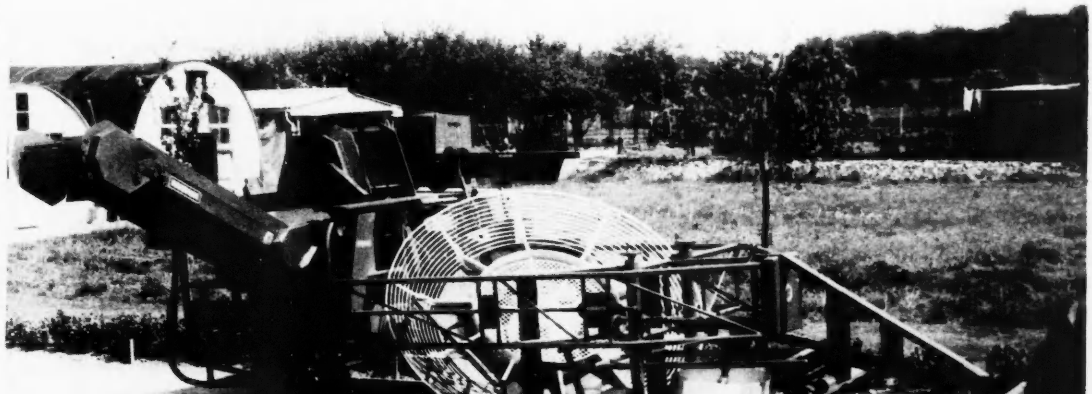

TABLE II. NRDC LICENCE PORTFOLIO (Cumulative)

	1950–51	1951–52	1952–53	1953–54
Licences Negotiated	20	61	131	177
Licences Assigned from Government Depts.	104	138	127	95
Total	124	199	258	272

Average revenue £250 a year for live licences (many still in the pre-production stage).

CURRENT POSITION OF NRDC PORTFOLIO
(as at April 30, 1955)

	Number of U.K. Patents and Applications	*U.K. Licensees**
Government Departments	690	224
Research Councils	57	27
Universities	99	10
Research Associations	24	6
Computer Project	166	2
Private and Miscellaneous (excluding Subsidiary Companies)	22	7
Total	1058	276

* *Many licences cover several patents each.*

recording, atomic and astronomical study, complex forecasting, etc.

The original group of patent applications assigned to the NRDC derived from Prof. F. C. Williams's work on cathode-ray-tube storage which he carried out at the Telecommunication Research Establishment at Malvern, and later at Manchester University. In 1950 the NRDC completed a licence agreement in regard to this whole block of patents with a large manufacturing firm in the U.S.A., where expenditure in this field is many times that undertaken in this country. To stimulate manufacture in Britain contracts were placed by the NRDC for the development of a large universal computer, and the production of six such machines which have since been sold commercially by the manufacturers concerned as agents of the Corporation. A second and smaller computer (the 401) was constructed by a second manufacturer to the Corporation's account, and the firm in question are now manufacturing commercially under licence. Supplementary development contracts have been placed in respect of various computer devices and features and the laboratories at Manchester and Cambridge Universities have been supported, thus enabling computer engineers to be trained for the new industry which the NRDC is thus helping to create.

Packman Potato Harvester. While great progress has been made generally in the mechanisation of agriculture, one outstanding requirement still remains. This is a satisfactory complete potato harvester that is effective in operation under widely varying conditions, and reasonably economic in its use of manpower. The development of such a machine is complicated by the fact that there are only a few months in the year when worth-while tests can be carried out, and it is inevitably therefore a slow, costly and commercially unattractive proposition.

A private inventor, Mr. P. J. Packman, approached the NRDC in 1950 for financial assistance in completing the design of his machine, on which he had already been working for some six years. Expert assessors advised that there was a reasonable prospect that when fully developed it would meet the needs of potato growers, and development assistance was accordingly provided between 1950 and 1953. As a result the performance of the machine under various conditions has been improved markedly. It has now reached the stage when it is ready for commercial production, and a contract and licence for this purpose have accordingly been negotiated with a north-country engineering firm, which will complete a number of machines in time for this year's harvest.

Hecogenin. The need arose for a suitable raw material from the U.K. or Commonwealth resources for the production of the drug, cortisone. Medical Research Council workers discovered that the juice and waste of the sisal plant which is grown on a very large scale in British East Africa contained quantities of a rare chemical—hecogenin, which formed a convenient starting compound for the synthesis of cortisone and similar steroid hormones. The rights in this process were transferred to the NRDC who progressively organised laboratory development with the East African Industrial Research Board, contracted with a sisal estate in Kenya for the construction and operation of a pilot plant and then participated in the underwriting of a large production plant in Tanganyika. A contract was also placed with a Scottish firm for the purification of the crude material received to yield a chemical complying with the specification of the pharmaceutical industry. The transfer of the project to industry on a licence basis is now being arranged.

Small Gas-liquefying Machine. Dr. Sixsmith of the Physics Department of Reading University, designed a small machine for liquefaction and fractionation of gases, based on the principle of a very small gas-turbine running at some 250,000 revs. per minute, and involving an ingenious design with special bearings. Patent applications in respect of a number of features were filed and assigned to the NRDC, which placed a development contract with the university for the building of the first experimental model. This model has now been completed and is under test.

Small Steam Prime Mover (Ricardo Engine). Some four years ago it was brought to the notice of the NRDC that the Indian Government was interested in the possibility of designing and developing a small prime mover which could "live on the land" and be independent of imported petroleum fuels. In association with Sir Harry Ricardo, the NRDC has financed the design and experimental construction of a small steam engine and boiler which could use low-grade fuels such as sawdust, brushwood and peat. Preliminary tests in this country and inquiries abroad have indicated that there should be widespread uses for such a prime mover in under-developed territories throughout the world, and numerous inquiries from such territories have been received. The stage has now been reached

for industry to take over the further development, production and marketing of the unit as a commercial venture.

Other Projects. These include the well-known Chick-sexer and Aural microscope, the Photogrammetric Plotting Machine and printing of Electronic Circuits. (For fuller details of the last mentioned see the article by C. L. Boltz in DISCOVERY, May 1955, pp. 201–3.)

INFORMATION FOR INDUSTRY

The Corporation's "exploitation" operations involve the direct licensing to industry of patented inventions which are more or less ready to manufacture and sell commercially. The NRDC employs various means to notify industry, including direct communication and the publication of a bulletin at regular intervals. Full particulars are supplied to interested firms and a discussion arranged with the inventor at his research department.

If after thorough investigation the firm is interested in commercial marketing a licence agreement is negotiated on reasonable terms. In special circumstances the NRDC may agree to an exclusive licence with certain safeguards.

The NRDC is required, special circumstances apart, to limit its licensing to firms "engaged in the industry concerned". This has in marginal cases created some teasing problems but while the NRDC has avoided introducing unfairly competitive elements into the recognised industrial pattern it does not refrain from licensing progressive firms who are in any event planning to extend their fields of activity. In certain cases with the approval of the Board of Trade, NRDC licensees have been given sufficient initial orders to enable them to initiate production to prove the market.

The widened terms of reference of the Corporation, coupled with an increased knowledge of its functions and responsibilities among scientific workers has resulted in new projects—some major, some relatively minor—being initiated by the NRDC at regular intervals. The Corporation can often arrange an assessment of the worthwhileness of a new invention or technological concept at a moderate cost; should this be favourable but indicate that further work is required not infrequently industry may be prepared to take the project over at its own further expense. The Corporation is thus left to handle the more speculative and more long-term projects, and this trend will probably continue.

In the last year the NRDC has devoted increased attention to its overseas patent rights. Its primary intention is to safeguard British exports, but when for various reasons the British manufacturer cannot adequately export to meet an overseas market, then efforts have been directed towards overseas licensing, particularly of American firms. The Corporation now has its own representative located at Washington. To date some ten overseas licences have been negotiated and others are in hand. NRDC has also entered into a reciprocal arrangement with Canadian Patents and Developments Ltd.

The statistics set out in Tables I and II require a word of explanation and must be read with reserve. They relate to individual patents and applications. This is not a wholly satisfactory index as from the NRDC point of view an invention may comprise one patent or a group of, say, twenty. These figures do show, however, that of the 2552 patents from the public sector submitted in the past five years the majority (1933) have so far been accepted; of these some 885 (45%) have found no use and so have been abandoned or allowed to lapse. Of the present U.K. portfolio of 1058 some 50% are the subject of licences; some 125 (12%) are being discussed with industrial firms, and the remainder (38%) includes mainly long-term and new cases. At any given moment about 250–300 are under active exploitation.

About four-fifths of licences negotiated concern Governmental inventions. These have either been developed for defence purposes and subsequently found to have non-defence applications, or are based on research of a civilian character, from which an invention of interest to industry has emerged. The majority of non-defence research results are not of an inventive character, and so are not brought to the Corporation's attention.

There has been much discussion recently on the relative importance and merit of patents and "know-how". In manufacturing industry, particularly in the chemical and chemical engineering sectors, patent licence deals between manufacturing organisations normally include special arrangements relating to "know-how" and sometimes even cover "know-how" only when there is no relevant patent. Patents, however, can serve as bargaining counters and do provide a convenient basis for business agreements, especially as development work often moves away from the original patent position so that in the end only a small number of the features claimed may be employed. Nevertheless in the Corporation's experience it is not easy to make a mutually satisfactory and watertight agreement where the patent protection is restricted; "know-how" and patents support rather than displace or replace each other.

To conclude, the NRDC is an experiment. Its work takes it into a very wide variety of scientific, industrial and commercial fields within its overall terms of reference that it shall assess, develop and exploit in the public interest. New weedkillers, separation of oil/water emulsions, the latest antibiotics, scientific instruments, etc., have been among the projects the Corporation has recently handled. In every case the NRDC endeavours to help the project forward in the interest of the country, the manufacturing firm who will take it up and the inventors who brought it into being.

* * * *

(We cannot undertake to handle any inquiries prompted by this article, and they should be sent direct to the NRDC whose address is: 1 Tilney Street, London, W.1. Industrial firms who would like to receive the NRDC Bulletin should also apply to the Corporation. Editor, DISCOVERY.)

AN ASTRONOMER'S VIEWS ON INTERPLANETARY TRAVEL

J. G. PORTER, Ph.D., B.Sc., F.R.A.S.

To the astronomer the idea of observing the heavens from space has an immediate appeal. No air, no mist or dust, no restrictions on size, since the telescope will weigh nothing at all—all these ideals can be achieved in space, and the value of the resulting observations can only be imagined. And yet some element of doubt creeps in—the instrument must be built out there in space, to endure on one side the heat of the sun and on the other the cold of space, while its electric motors run in a perfect vacuum. But let us take heart! The engineer has the answer to all this, and he tells us that it *will* work. In fact he tells us about many things that will work, for it is the engineer, and not the astronomer, who talks so glibly about sending a pilotless rocket to Mars, and of space-ships making a cushioned landing on the moon.

The general idea is sound enough. Any object that is thrown up from the surface of the earth will travel in an orbit, usually an ellipse with one focus at the centre of the earth. Give the object enough speed and it will go as far as the moon, returning, if it is not interrupted, to the place of origin. This is precisely the principle of space travel. The ship is given an initial impulse sufficient to provide the necessary speed, and having acquired that speed it continues for ever in the orbit. There is no other driving force, for the ship is simply "falling" freely in a gravitational field. The necessity for travelling in such an orbit is dictated solely by the need for economy of fuel. Other types of orbit are possible, but these would entail an abundant supply of energy; the free fall orbit is the only one in which fuel is not used.

Now economy always imposes restrictions, and it is important to realise that these enter right at the start of the journey. The earth is the controlling body, and the ship starts from a point not far removed from the centre. This will be the perigee of the orbit (the point nearest to the earth) while the apogee will lie on the moon's orbit. Now perigee and apogee must be at opposite ends of the major axis of the ellipse, so that the ship must always start on the side of the ellipse away from its destination. Thus it will begin its trip to the moon from the side of the earth opposite to that which faces the position the moon will occupy 120 hours later. Similarly, on a trip to Mars, the ship will start from the earth when the longitude of our planet is 180 degrees different from that of Mars at the time of arrival nine months later. Clearly the exact time of setting out is important, but this is easily arranged.

The initial speed, however, will be more difficult to control. The engineer has shown us how the start can be made. A three-stage rocket can be used to carry material to outer space where a landing-stage can be constructed—a permanent vessel revolving continuously in an orbit about the earth, thus forming an artificial satellite (Fig. 1). This Earth Satellite Vehicle (E.S.V.), whose military advantages have already captured the imagination of the authorities of some countries, will then serve as a stepping-stone to the moon and the planets. In one typical scheme, the satellite will revolve in the two-hour orbit (see Table I) so that its speed is more than 4 miles per second. The space-ship, moored alongside, will share this motion, and to start on its journey an increase in speed of about 50% is all that is necessary. In order to reach the moon a speed of about 6·14 miles per second is required, but the size of the orbit, and therefore the distance of the apogee, is extraordinarily sensitive to this initial speed. In Table II the values of Q, the distance of the apogee (in thousands of miles), is given for different values of the initial speed; the time to reach this point and the speed at apogee are also given. The interesting fact emerges that in order to reach the moon at 240,000 miles, the initial speed must be controlled to something better than a thousandth of a mile (about 5 feet) per second! And in considering the error that would result from an error in this speed, it is not only the distance that matters, but the time. An error of two or three thousand miles is neither here nor there in space—but to arrive two hours late for an appointment with the moon might prove disastrous!

If the speed were increased to 6·202 miles per second

TABLE I
SATELLITE ORBITS

	Radius miles	*Speed miles per second*
The two-hour orbit	5050	4·363
The 12-hour orbit	16700	2·401
The 24-hour orbit	26500	1·905
The Moon (27·3 days)	240000	0·633

TABLE II
MOON ORBITS

Initial speed miles per second	Q $\times 1000$ *miles*	*Time to Q in hrs.*	*Speed at Q miles per second*
6·137	234·8	115·7	0·131
6·138	238·5	118·3	0·129
6·139	242·4	121·1	0·127
6·140	246·3	124·0	0·125

TABLE III
LANDING ON THE MOON

V	0·05	0·1	0·5	1·0	2·0 m.p.s.
S	1·48	1·48	1·56	1·78	2·49 m.p.s.
Max. d.	32000	16000	3400	1900	1300 miles

the ship would leave the satellite orbit, and the earth, never to return. This is the escape (or parabolic) velocity at this particular distance from the earth, and it represents the border-line case between the closed curves (circles and ellipses), and the open curves (hyperbolas) which will carry the ship away from the centre of attraction for ever. Parabolic velocity is not attainable in practice—orbits are either ellipses or hyperbolas, and in accepting the principle of free fall, we implicitly accept the fact that *a space-ship must always travel in an elliptical or hyperbolic orbit.*

Yet this is often forgotten. There is, for example, a curious delusion that there is a "neutral point" between the earth and the moon where the attractions of the two bodies just balance. This leads to the idea that all that is necessary is to send the ship just beyond the neutral point, after which the moon takes charge and the ship falls on to the moon. If the moon and the ship would obligingly stand still in space this idea would be more sensible; but in fact the moon is moving in its orbit at 0·633 mile per second, while the ship at apogee travels 0·128 mile per second. Hence the moon is overtaking the ship at 0·505 mile per second (Fig. 2) which is greater than the parabolic velocity at any distance greater than about 9000 miles from the moon. If the speed of the ship exactly matched that of the moon, it would be at rest relative to the moon's surface, and would therefore fall. Under other circumstances there is only a very restricted range of orbits which would intersect the moon's surface from a given distance. We know a great deal about this subject from our study of meteors. Shooting stars fall on the earth in millions every day, each one a grain of dust that has been attracted by the earth. This attraction forces the particle into a hyperbolic orbit about the earth's centre. If it happens to be near enough, it will intersect the earth's surface with a speed S which is given by $S^2=V^2+P^2$, where V is its original velocity (without the earth's attraction), and P is the parabolic velocity at the earth's surface. The same principle applies to a space-ship, and it is clear from this that the speed of fall on to the moon will always be greater than the parabolic velocity, while it is only from orbits that pass within certain limits of distance (Fig. 3) that a fall is possible. In Table III are given the maximum distances from the moon which will allow a grazing landing; these distances will be seen to be quite small.

Clearly the correct procedure is to increase the speed of the ship until it matches that of the moon. The ship is then at rest relative to the moon, and no matter what its distance, the moon will take control and the ship will fall on to its surface. Thus two changes of speed are necessary—one to equalise the speeds, and the second to act as a brake during the subsequent fall. It is not difficult, of course, to see that the moon will take charge before the velocities are equalised so that the ship will begin its fall in a hyperbolic orbit. Its angle of approach to the moon's surface will not be a right angle, and in fact neither a perpendicular descent nor a choice of landing-place seems at all possible, without a great expenditure of fuel. The same remarks apply to a landing on Mars or any other planet, but it seems to

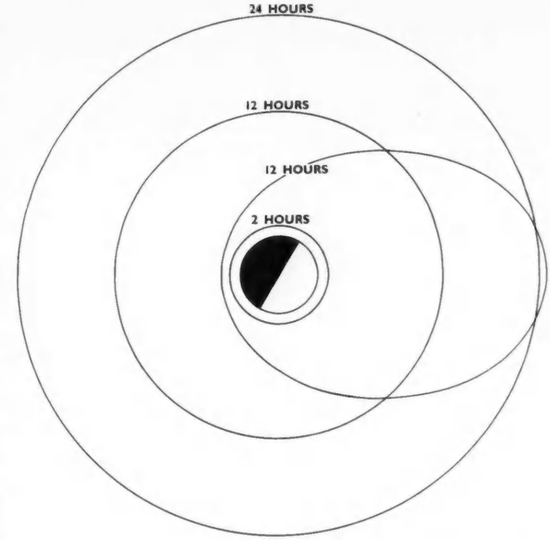

FIG. 1. Earth satellite orbits. (Diameter of earth 7920 miles.)

be taken for granted by writers on this subject that landing is a simple "fall", and all space-ships are drawn standing on their tails having made a perfect three-point landing! Yet unless the distance and velocity are controlled within quite narrow limits, the ships cannot land at all.

The return to earth, we are told, will be much easier. The only reason for this statement appears to be the smaller parabolic velocity (only $1\frac{1}{2}$ miles per second) on the moon. But the ship will have to leave the moon from the place where it landed, and at right angles to the surface. Only the speed and the time of starting can be controlled, and there will have to be further changes in space to get the ship into an orbit that will reach to the earth. This is merely another example of the type of careless statement about space travel that will not stand the test of examination in detail. The essential importance of the orbit seems to be consistently overlooked. One gains the impression that one chapter about orbits is enough; having got that out of the way we can pass on to other aspects of space travel. There are no other aspects, for the free fall orbit dominates everything.

Consider, for example, the neglected subject of navigation in space. While we may be prepared to accept the fact that a journey to the moon is a possibility of the near future (but only because the entire trip can be controlled by radio) the voyage to Mars is an entirely different matter. It is 1600 times as long as the moon trip and, at the enormous distances concerned, radar control would be out of the question; while the time-delay in sending and receiving radio signals would make advice from the home base somewhat out of date by the time it arrived. Yet constant navigation would be essential, because the initial conditions are even more

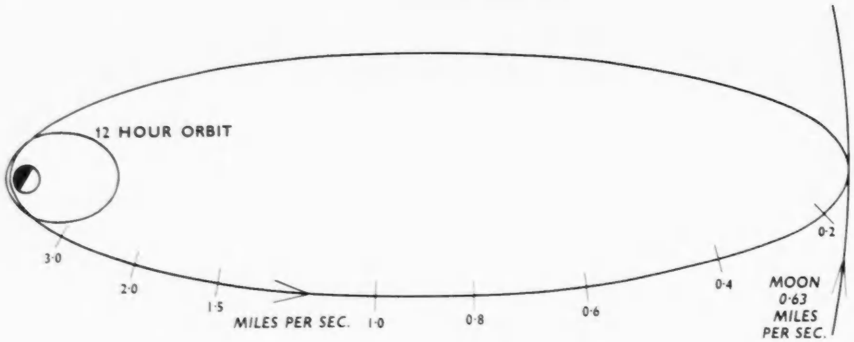

FIG. 2. The earth-moon orbit, showing changes in speed. The 12-hour orbit shown in Fig. 1 is included for comparison.

exacting than they are in the case of the moon. The moon orbit is controlled by the earth, but the orbit which reaches to Mars has its focus at the sun, and the ship must be given sufficient speed to travel in the correct orbit and also to escape from the attraction of the earth. The speed must therefore be greater than the parabolic velocity of 6·202 miles per second, and it follows that the ship will not at once go into the correct orbit round the sun, but will first enter a hyperbolic orbit about the earth, which will tail off eventually into the true elliptical orbit. Writers on this subject seldom make this point clear; they give what are called "characteristic velocities", which may be suitable for rough estimates of fuel consumption, but do not give any idea of the real speeds that are needed. Yet the problem is exactly the same as that of landing on the moon, for it is clear that the speed which must be given to a ship to escape from the earth to reach Mars is precisely the same as that which the ship would have when landing on the earth from the same orbit. Hence we can use the same formula, and since the earth's speed is 18·5 miles per second and we must increase this to 20·7 miles per second, we put $V=2{\cdot}2$ miles per second as the relative speed required in the orbit, and $P=6{\cdot}202$ miles per second for the escape velocity; we then have $S=6{\cdot}58$ miles per second. This is surprisingly little more than that needed for the moon trip, but it must be controlled with the same accuracy, that is to within a few feet per second.

The effect of an error in the angle of projection may be discussed in much the same way. The main effect here is to turn the orbit round through an even larger angle, and also to alter the shape of the ellipse. The errors are not serious in the case of the moon, but the great distances in the Martian orbit make it essential to control the initial angle within a very small fraction of a minute of arc. At the other end of the journey, the landing on Mars will present the same problems as those in the case of the moon. It has been suggested that the satellite Deimos would be more suitable as a terminus. The reader may like to ponder on the problem of converting the motion of the space ship in the Earth–Mars orbit to match that of Deimos, which is revolving about Mars in a circular orbit inclined at an angle of 24 degrees to the plane of the Martian orbit!

This brings to mind the fact that none of these planetary or satellite orbits are in the same plane, so that somewhere *en route* the space-ship will have to change course. Clearly navigation is essential at every stage of the journey—but how does one navigate a space ship? Let us divide the question into two parts: (1) how does one determine the orbit in which the ship is travelling? (2) how does one change course if necessary? It should be noted that it is not sufficient to determine the position of the ship. This may be an interesting piece of information, but since the ship will be travelling at some 70,000 miles an hour, the really essential points to determine are the direction of motion and the actual velocity at the time. *There is no known method for doing so.* The earth is really a huge space ship, but its great speed is never realised by its inhabitants. Nobody can look up at the stars and find the earth's speed and direction of motion by making a few measurements. Long and laborious calculations derived from repeated measurements of the sun day after day are necessary, and this applies equally to a space-ship. The crew will be quite unconscious of any movement, of any sense of direction. Repeated measurements of their position day after day will, of course, tell them the orbit in which they are moving. But the calculation of a position will involve some very complicated mathematics, since three angles are needed in space, and these

FIG. 3. Path of a space-ship relative to the moon. The original orbit is that of Fig. 2. The distance d is the minimum possible for a landing without altering speed. (Diameter of moon = 2160 miles.)

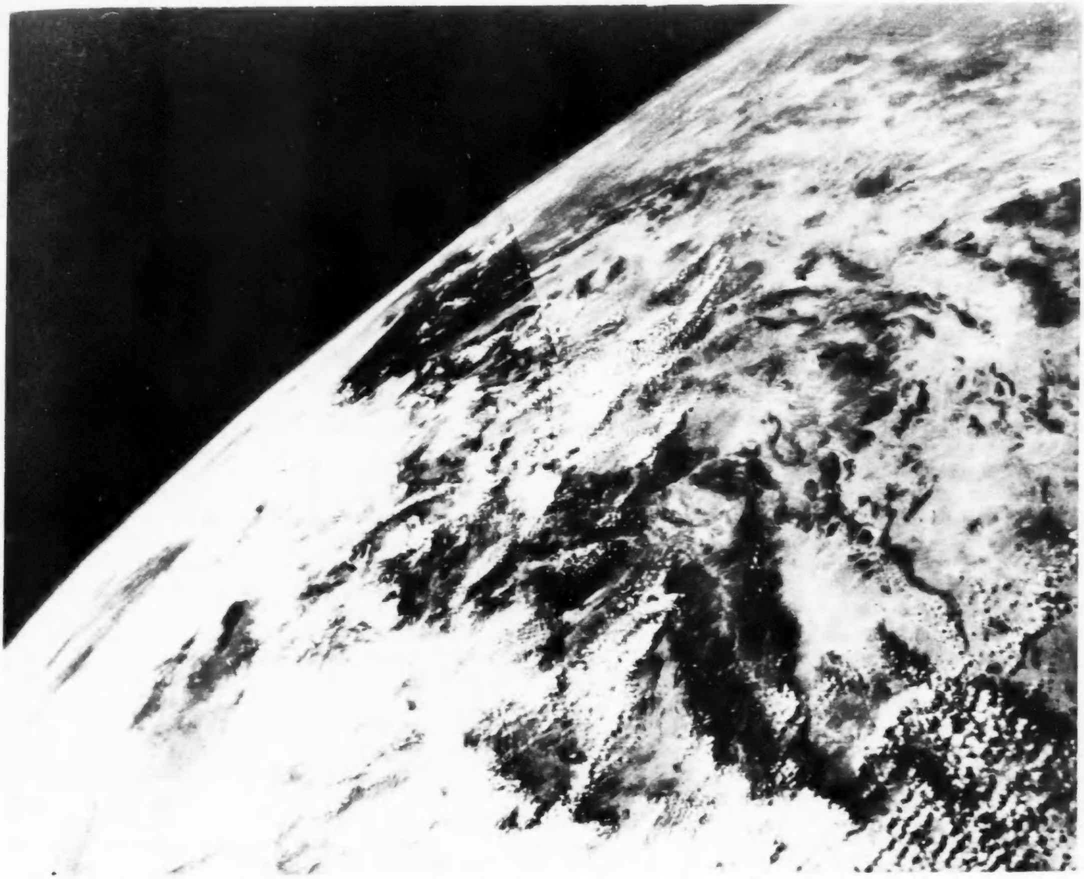

FIG. 4. The earth as an astronaut might see it. This composite photograph was built up from pictures taken by a Viking rocket about 150 miles above the White Sands Proving Ground, New Mexico: the distance from camera to the horizon was about 1100 miles. The area of earth shown is nearly 600,000 square miles.

angles must be measured with considerable accuracy. Thus a second of arc at the distance of the sun represents 450 miles, and at the distance of Jupiter it is five times as much—and it is doubtful whether we know the positions of the planets with any greater accuracy than this. The sextant is out of the question for this sort of navigation.

Now in order to determine an orbit six quantities must be known for any given instant. At the start of the voyage, for instance, the position of the ship at that moment provides three quantities, namely the x, y, z co-ordinates in space. The speed and direction of motion similarly provide the three components of the ship's velocity. These six quantities define the size, shape and orientation of the orbit, and once they are fixed, *not one of the six can be altered without changing the orbit completely*. The usual method of changing course must be by means of rocket motors, but the application of a thrust in any direction will change the speed, and hence the orbit. There are no straight lines in space travel, and it is quite impossible to steer a space-ship in free fall in the ordinary sense of the word. The pleasant picture of one space-ship putting on speed to catch up with another in the same orbit is just another illusion. The increase of speed will at once put the ship in a larger orbit (compare Table I), but it will also in most cases alter the shape of the ellipse and turn its axes through an angle about the sun. The effect is quite negligible at short distances, but at the beginning of the trip such manœuvres would have disastrous results on the speed and time of arrival at the distant planet.

Thus it would seem that every use of the motors in space will call for a second burst of power to correct the unwanted alterations to the orbit. This builds up a rather frightening picture of a sort of zig-zag course through space, and reduces to zero the advantages of the free fall orbit. The answer to all of these difficulties is to have a constant drive for the ship. With the advent of plentiful atomic power it would be possible to drive

the ship continuously. Not only would this provide an acceleration which would act as an artificial gravitational force for the benefit of the crew, but it would build up enormous speeds and would do away with the necessity for these intricate pieces of navigation. The ship could be driven in approximately the right direction, changing course as necessary. The voyage to Mars would become a trip of a few weeks instead of months—but this is looking far ahead. We may yet see an artificial satellite of the earth built with the present type of motor, but if it does nothing else, it will at least open the eyes of its builders to the difficulties that lie ahead.

READING LIST

Two papers have been published by Dr. Porter which would interest those who wish to read further into this subject. These are: "Interplanetary Orbits", *J. Brit. Interplanetary Soc.*, 1952, vol. 11, p. 205; "Navigation without Gravity", *J. Brit. Interplanetary Soc.*, 1954. vol. 13, p. 68.

A great many books on interplanetary travel have been published, of which the following selection can be recommended:

Bonestell, C. and Ley, W., *The Conquest of Space*, London, Sidgwick & Jackson, 1950.

Clarke, A. C., *Interplanetary Flight*, London, Temple Press, 1950.

Clarke, A. C., *The Exploration of Space*, London, Temple Press, 1951.

Haber, H., *Man in Space*, London, Sidgwick & Jackson, 1953.

Ryan, C. (Ed.), *Across the Space Frontier*, London, Sidgwick & Jackson, 1952.

Ryan, C. (Ed.), *Man on the Moon*, London, Sidgwick & Jackson, 1953.

CLOTHING RESEARCH

In spite of extensive research, particularly in Canada, nobody has yet succeeded in producing Arctic weather garments as effective as those worn by the Eskimos.

Typical Eskimo clothing, usually made from caribou skins, works on the simple principle of producing an insulating layer of "dead" air *and preventing its escape*. The garments have the minimum number of apertures, are without buttonholes and the neck and hood always fit firmly.

The research which led to this realisation about the supreme role of dead air in providing the best insulation obtainable and the developments resulting from this research are fully described in an excellent new monograph produced by the Physiological Society and entitled *Man in a Cold Environment*. Its authors are Prof. Alan Burton of the University of Western Ontario and Dr. Otto Edholm of the National Institute for Medical Research, London.

Actual measurements of the insulating properties of clothing have produced some surprising results. If the fingers are insulated by a covering which does not establish a layer of trapped air but merely "lags" them they become *colder* than they would without any protection. This holds until the thickness of the wrapping exceeds one-quarter of an inch. This finding is linked with the fact—known to physicists, but not apparently to many engineers—that lagging a pipe which is less than one-quarter of an inch in diameter *increases* the heat loss from it. The lagging increases the area losing heat to the air to a degree which outweighs the small gain in thermal insulation.

Such factors show the need for careful measurements in the designing of clothing for extreme temperatures. To assist such measurement the physiologists have introduced a unit called the *clo*. This has been defined as "the amount of insulation which will maintain a sitting man whose metabolism is 50 calories per square metre per hour indefinitely comfortable in an environment of 70°F, relative humidity less than 50% and air movement 20 feet per minute". In practice it can be visualised as the insulation provided by the clothing of sedentary workers in comfortable indoor surroundings. The business suit and underclothes worn by the average European man provides about 1·3 clo units of insulation. Americans wear about 0·7 clo indoors as a result of central heating.

The skin and superficial tissues provide some natural insulation which averages about half a clo but varies widely in different individuals depending on the thickness of the subcutaneous fat. In exceptionally plump people this layer is very thick and provides remarkable protection against cold. Tests of men and women swimmers made immediately after they had swum the Channel last year showed that their body temperatures had barely fallen one degree. This was true whether they had covered their bodies with grease or not. One fat swimmer tested at the National Institute for Medical Research could lie in a cold bath and read in comfort for more than an hour. A thin scientist who tested himself under the same conditions for comparison was paralysed with cold in 40 minutes and had to be assisted from the bath.

The amount of thermal insulation normally needed for comfort varies, of course, with the activity of the body. At freezing-point a man doing very heavy work should be amply protected by little more than 1 clo, but at rest he would need the protection of nearly 6 clo. Even at minus 40°F metabolism provides so much body heat that about 2 clo of protection is sufficient during very heavy work.

The maximum amount of clothing a man can wear without being almost completely immobilised supplies about 6 clo.

Man's greatest needs for insulation occur during sleep. The bedclothes in an unheated English bedroom must provide about 6 clo for comfort during winter. It is rarely in this country that the naked body's insulation is sufficient to provide comfortable insulation at night.

Dr. Edholm and his team at the National Institute for Medical Research are currently working on the design of clothing for the forthcoming Antarctic expedition.

REFERENCE

Man in a Cold Environment by Prof. Alan Burton and Dr. Otto Edholm (London, Edward Arnold, 1955. 273 pp., 30*s*.)

HIGH-TEMPERATURE PHENOMENA

PROF. G. O. JONES, M.A., B.Sc., Ph.D.

This is the first of three articles in which Prof. G. O. Jones, who is Professor of Physics at Queen Mary College, will discuss the physics of extreme conditions. The second article will be concerned with Low Temperatures, and the theme of the final article will be High Pressures and High Densities.

The physics of matter under extreme conditions of temperature and pressure covers many phenomena which are not only spectacular but fundamentally interesting as well. The nature of the sun's corona and of white dwarf stars; the properties of liquid helium and the artificial production of diamonds; all of these have striking and fascinating aspects, and they are also of great scientific interest. Moreover we find that by studying some of these extreme phenomena we learn much that is relevant to the understanding of what lies between.

THE MEANING OF TEMPERATURE

We first need to consider the meaning of *temperature*. In formal thermodynamics, temperature is defined as the property of a system which determines whether it will be in thermal equilibrium with other systems. Subsequently, thermodynamics tells us how to set up a scale of temperature in terms of the efficiencies of the somewhat hypothetical machines known as Carnot engines. Now in the necessity for such a scale there lie hidden certain profound truths about the general nature of matter which we have to discuss later. However, we are so far not told anything about the actual behaviour of pieces of matter, and in order to be able to understand something about this we have to add that there is a quantitative relationship between temperature and energy in all actual systems, high temperature being associated with high energy and low temperature with low energy. The precise form of the relationship depends upon the nature of the particular system and of its constituent particles, and upon what kinds of energy it and they can possess. However, in all cases the quantity of energy kT, which we denote by ε, has a special significance in the neighbourhood of the temperature T (k is Boltzmann's constant and T is the temperature measured on the Kelvin absolute scale), and it is instructive to examine this relationship further. In Table I corresponding values of T and ε are listed, together with some typical physical processes which involve in some way energies (per particle) of the particular order of magnitude. The last column gives the wavelength of electromagnetic radiation which corresponds to the particular value of ε according to the formula:

$$\lambda = \frac{hc}{\varepsilon}$$

This is derived from the equations

$$\lambda = \frac{c}{\nu} \text{ and } \varepsilon = h\nu$$

where c is the velocity of light and ν the frequency. The former equation is, of course, a particular case of the general relationship between velocity, wavelength and frequency which holds for all types of wave. The rather cryptic equation $\varepsilon = h\nu$ is the basis of quantum theory, and relates the energy of a *photon*—that is, of light regarded as a particle, with its frequency—when the light is regarded as a train of waves. Its significance may be illustrated by an example: if an atom absorbs ultra-violet light it will do so in "packets" of energy of about 10 electron-volts; conversely, if it gives out this amount of energy because of a rearrangement of its electrons it will do so by emitting ultra-violet light. We can see by glancing at the table that nuclear physicists will be interested in γ-ray spectroscopy and chemists in infra-red spectroscopy.

Looking at the first two columns of the table, we find many different kinds of energy listed at different temperatures. For example, at the top of the table we have as an example the energy which has to be supplied, on the average, to detach one of the constituent particles from an atomic nucleus. Lower, we have the quantities of energy which have to be supplied to detach an electron from an atom, either from "deep" levels, or from outer (or "higher") levels, or to move an electron from one level to a higher level within the atom. At lower energies we have as examples the amount of energy which has to be supplied (per molecule) to separate the molecules of water to form steam, and below that we come to the still smaller energy needed (per atom) to separate the atoms in liquid helium to form gaseous helium. Finally, at the bottom of the table, there are a number of references to certain complex phenomena involving minute energies which will be discussed in detail in my second article, since they form the main content of low-temperature physics.

Now the *practical* meaning of temperature can be better understood. A particle (such as an atom) or a system of particles (such as a mass of water) will adopt a state of high energy at high temperature and lower energy at lower temperature. The first two columns of the table give rough quantitative expression to this broad assertion. More precisely we note, for example, that a large fraction of all molecules will be dissociated into atoms at 10^4 degrees, atoms will be largely ionised at 10^5 degrees, and nuclei will be largely dissociated into protons and neutrons at 10^{10} degrees, since these are all processes which require the absorption of energy to overcome the forces of attraction. Or, we can guess that ice will melt at a temperature of order of magnitude 10^3 degrees—actually it is of course 273°K. The reader will perhaps have noted for himself that this can only be a very rough picture since the "boiling-point" of

TABLE I

T = Temperature measured on the Kelvin absolute scale	ε = energy per particle measured in electron-volts.		λ (Wavelength in Angström units or centimetres)	
degrees K.				
10^{10}	10^{6}	binding energy per particle in atomic nuclei; energies of α-particles emitted in radio-activity.	10^{-2} A	*γ-rays*
10^{8}	10^{4}	atomic excitation energies in "deep" electron shells.	1 A	*X-rays*
10^{5}	10	atomic excitation (electronic) or ionisation energies.	10^{3} A	*ultra-violet*
10^{4}	1	chemical bond energies; latent heat of vaporisation of water.	10^{4} A	*infra-red*
10^{3}	10^{-1}	latent heat of fusion of water; spacing between energies of molecular vibrational levels.	10^{5} A	*far infra-red*
10	10^{-3}	latent heat of vaporisation of helium; zero-point-energy of helium; spacing between energies of molecular rotational levels.	10^{-1} cm.	*short micro-waves*
1	10^{-4}	spacing between energy levels corresponding to fine structure in optical spectra.	1 cm.	*micro-waves*
10^{-2}	10^{-6}	spacing between energy levels corresponding to hyperfine structure in optical spectra.	10^{2} cm.	*short radio waves*

water is much lower than 10^4 degrees. However, we need not worry too much about such a discrepancy when the table as a whole covers twelve orders of magnitude, and indeed it serves as a reminder that processes which differ greatly in kind will not be governed in quite the same way by the constant, k.

Some further examples must be given of the "order of magnitude" relationships between energy and temperature which enter into physics and chemistry. An important example is that of a gas at temperature T, in which the *average* kinetic energy per molecule is $\frac{3}{2}\varepsilon$—the actual energies range on either side of the average according to the so-called Maxwell distribution. Another example is illustrated in Fig. 1, showing how the energy contained in black-body radiation—a small hole in a furnace is an example of a black-body radiator—is distributed between the different wavelengths for different temperatures. At higher temperatures the curve as a whole moves to the left; this explains why a progressively heated body is first red-hot and then white-hot as more and more of the wavelengths of visible light are emitted. The maximum of any one of these curves (which are really curves of *Planck's radiation formula*) corresponding to a given temperature occurs at a wavelength whose magnitude is again of the order hc/ε.

It is useful to have in mind these general ideas about the meaning of temperature because it happens that at both high and low temperatures there are possibilities of eccentric behaviour in which application of the formal definition of temperature seems to be somewhat irrelevant. For example, in dealing with discharges in gases or with, let us say, the properties of the sun's corona, we may be told that the electrons present have one temperature and that certain ions have another. Or again, when one is considering interstellar space, the estimated temperatures of small material particles prove to be a few degrees above absolute zero, whereas the temperatures of atoms, ions and electrons are of the order of 10^4 degrees. Obviously there is something curious here because the use of the word "temperature" ought to imply that the given system is in thermal equilibrium. In these systems there is certainly no thermal equilibrium; there may be a flow of matter or radiation in or out of the system so that the different types of particle have no opportunity of reaching equilibrium with each other. However, it is still useful to use the term "temperature" in the rather more practical sense which has already been discussed. The assertion that a given class of particles had a certain temperature would then mean that their average velocities were the same as they would be in a gas of such particles in equilibrium at that temperature. There is, however, one important reservation to be made. The characteristic of heat energy is that it is *disordered* motion; in an ordinary gas, for example, the molecules move in all directions and also have a natural distribution of velocities (the Maxwell distribution already mentioned), which arises as a result of collisions between the molecules. Only when there is at least an approximately similar distribution of directions and velocities would we be really justified in assigning a temperature to any gas-like system of particles. We could certainly not claim that the sub-atomic particles accelerated to, say, 1000 million electron-volts in a modern particle accelerator, had a temperature of 10^{13} degrees, because their ordered coherent motion in a straight line or circle would be quite different from the thermal motions of particles actually maintained at such a temperature.

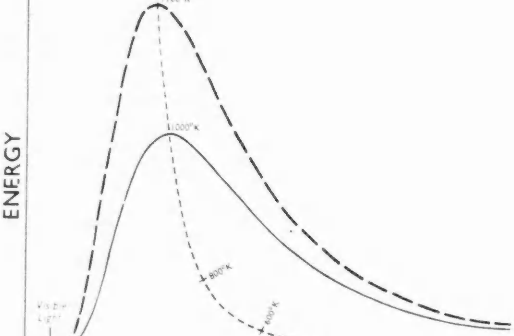

FIG. 1. Distribution of energy in the spectrum of different temperatures.

(We shall return in the next article to the question of the difference between disordered and ordered motion because of its importance in low-temperature physics.)

Finally, we need to note one important practical difference between the physics of high and low temperatures. As we have seen, the tendency in going from low to high temperatures is for all systems to break down into smaller and smaller units. This has the effect of making the associated theoretical problems much simpler. Moreover, the energy relationships are already well charted as a result of spectroscopy, at wavelengths which—as we see from the table—must range from those of γ-rays to the infra-red. Thus there are on the whole no surprises to be expected at high temperatures. At low temperatures, on the other hand, we meet the additional complications arising from interactions between particles as they are brought nearer together, and worse, a progressive change in the character of the theoretical problems from those of ordinary mechanics to those of the much more difficult types found in quantum theory. Also, there is an almost complete lack of supplementary data from spectroscopy because of the difficulty—which remained serious until fairly recently—of carrying out spectroscopy in the relevant range which, as we see from the table, must lie between infra-red and short radio waves. These facts help to account for the many surprises which have arisen in low-temperature physics.

HIGH TEMPERATURES

The outstanding "laboratories" of high-temperature physics are the sun and stars (see Fig. 2). However, if we start by looking at our own earth, it is most disappointing to have to record that very little of interest can be said about the earth itself as a source of high temperatures. There is no agreement as yet about the nature and temperature of the earth's core, current estimates of the central temperature ranging from a little above that of the surface to about 10,000 degrees. Even that most spectacular product of heat within the earth—the lava from an erupting volcano—is not usually much above about 1000°C.

In the terrestrial laboratory, high temperatures are normally produced by supplying heat either electrically, or chemically (as in flames). Under controlled conditions it is possible to raise the temperature by only one order of magnitude above the earth's surface temperature—to about 4000°C or perhaps 5000°C. Whether an electric furnace or a flame is used the main difficulty is to contain the experiment, since the most refractory elements—tungsten and carbon—melt below 4000°C and the most refractory "refractories" cannot be taken above about this temperature. There is another fundamental difficulty arising from the fact that the thermal radiation emitted by a hot body increases as the fourth power of the absolute temperature: doubling the temperature increases the loss by radiation by a factor of 16. The amount of energy which has to be supplied to maintain a body at high temperature thus increases very rapidly as the temperature is increased. The problem of concentrating the heat energy where it is wanted

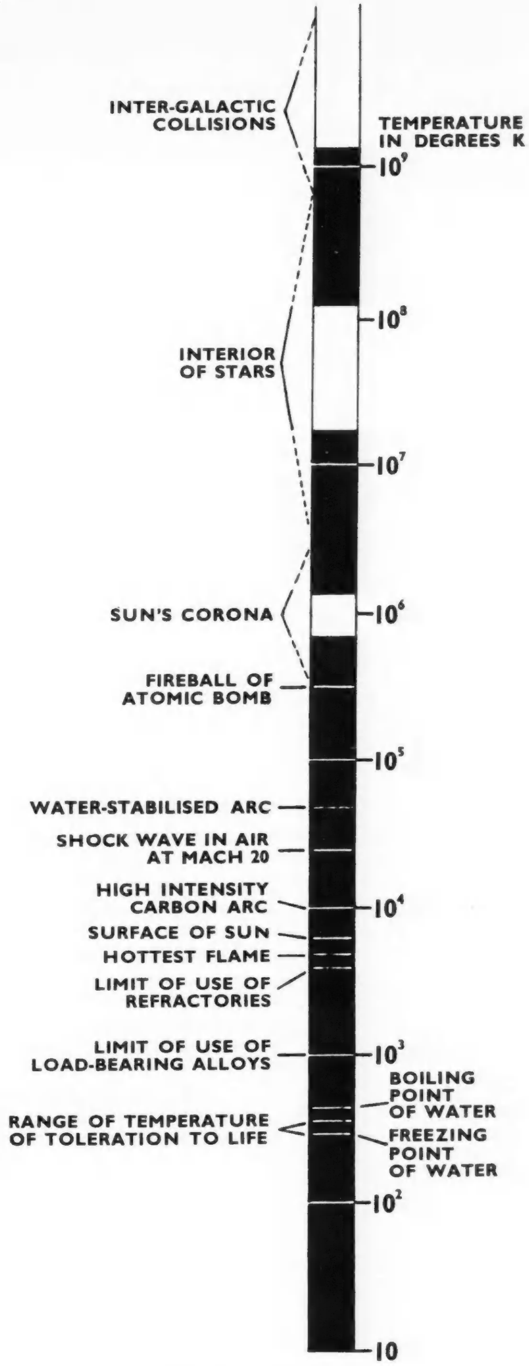

FIG. 2. Occurrence of high temperatures in the universe.

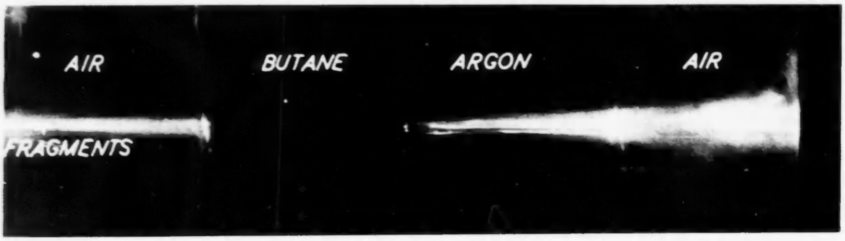

FIG. 3. Luminosity in shock waves.

becomes acute above about 3000°C and special methods have to be used—such as induction and high-frequency methods, or one based on the schoolboy's burning-glass in which sunlight is concentrated by large mirrors. The latter method has recently attained some practical importance, and it has the special virtue that it can be used to heat specimens *in vacuo*.

In trying to reach still higher temperatures we usually find that a good deal of our control over the experiment has to be sacrificed; the high temperature is generated only for a very short time, or in a very small space, or in very specialised circumstances which cannot be made use of—except perhaps to give us the satisfaction of estimating what the temperature is. Dismissing as curiosities the electric spark (in which temperatures up to 15,000 degrees may be reached) and the low-pressure gas discharge (in which the free electrons may have energies corresponding to 60,000 degrees although the gas itself may be little hotter than the walls of the tube), we come to the well-known carbon arc. In its ordinary pre-war form it could reach about 5000°C if run in a high-pressure atmosphere. There have however been some rather spectacular recent developments which enormously increase its range. It has been found that the passage of a very intense current sufficient to "boil" the carbon causes a sudden change in the character of the arc leading to a rise in temperature up to perhaps 10,000 degrees. If another material is mixed with the carbon and incorporated in the poles it also can be heated to such temperatures and this method has already been tried in the U.S.A. at "pilot plant" level as a method for the refining of beryllium ore. Still higher temperatures—up to 50,000 degrees—have been reached in the *water-stabilised arc* developed at Kiel. Here the arc is run through the central eddy region of a water turbine. The water serves to confine the arc to a channel of diameter of a few millimetres and also takes part chemically by dissociating into hydrogen and oxygen. So far, the main interest has been in establishing the value of the temperature by studying the spectrum of the hydrogen in the arc.

SHOCK-WAVES

We should have to leave the earth at this point in our search for high temperatures if it were not for two other recent developments: shock waves and atomic bombs. Published information on both topics is probably somewhat out of date, but we can mention here some points of interest about shock-waves. The question of nuclear reactions, which provide the release of energy in atomic bombs, is later discussed in more general terms in connexion with the temperatures of stars.

A shock-wave is essentially the progress of a sharp pressure discontinuity through a fluid, and in the neighbourhood of the shock-wave "front", high temperatures are generated. The pressure discontinuity may be caused by the very fast motion of an aircraft or projectile, or by an explosion. In a simple device known as a *shock tube*, such a pulse can be started by allowing a diaphragm separating regions of high and low pressure to fracture. For a pressure ratio of about 500, in the most favourable case, a velocity corresponding to Mach 20 (that is, twenty times the velocity of sound) should be reached, and in argon this would be expected to give a temperature of about 16,000 degrees—which is sufficient to cause appreciable ionisation. Velocities at least up to Mach 34 have actually been reached experimentally in shock tubes. Obviously dissociation and ionisation must occur in the neighbourhood of a shock-wave front, and although in published accounts the experimental situation is somewhat confused, it has been shown by many workers that there is a luminous region associated with a shock front moving sufficiently rapidly, and that the shock front is a highly conducting region and therefore ionised. Several curious effects have been reported; for example, a faintly luminous region *ahead* of the shock-wave front is often seen, and this is thought to be caused by radiation from the intensely luminous front. At present one of the most promising approaches for the generation of very high temperatures seems to be to cause shock-waves to overtake or collide with each other, or to meet some other barrier. It has been suggested that such high temperatures might be attained by such methods that they could be used to "detonate" hydrogen bombs. (It has usually been assumed that a conventional atomic bomb would form the detonator of a hydrogen bomb.)

In Fig. 3 is shown an interesting photograph illustrating the luminosity along the tracks of fragments moving through cellophane compartments containing air, butane and argon. The temperature reached depends largely on the quantity γ—the ratio of the specific heats at constant pressure and constant volume. This quantity has a low value for complex molecules and a high value for simple (such as monatomic) molecules, and in this figure the low luminosity in butane (with low γ) and the high luminosity in argon (with high γ) are clearly seen.

Matters of this kind are naturally becoming important in the aerodynamics of supersonic flight. Not only are the fluid properties of air altered by the ionisation and

dissociation in the shock-wave, but there is the possibility of appreciable heating of the aircraft by friction caused by its passage through the air. It is now thought that this may ultimately set the limit—the so-called "heat barrier"—to the speed of flight.

THE SUN AND STARS

Now we come to the most important sites of high temperatures—the sun and the ordinary stars. They are spheres of gas at high temperatures and pressures, more or less in mechanical equilibrium under the action of the gravitational attraction, the ordinary gas pressure, and the pressure of the electromagnetic radiation. This "radiation" pressure varies as the fourth power of the temperature and can be of the same order of magnitude as the gas pressure at the high stellar temperatures. It can easily be shown mathematically that only large stars of this kind can be in equilibrium. We see in the example of the atomic bomb—which creates temperatures of about 10^6 degrees—how short would be the life of a very small hot star, with its relatively greater ratio of surface to volume and hence greater loss of energy by radiation, and its relatively smaller gravitational energy. The futility of hoping to perform on earth controlled experiments at intensely high temperatures is thus demonstrated.

The sun is a fairly typical star and, of course, much more is known about it than about other stars. The most immediate matter of interest is that it behaves optically as a surface at a temperature of about 6000°K. This follows from a comparison of the energies received at different wavelengths with Planck's formula (see Fig. 1). It is important to realise that the validity of this statement does not depend upon assuming that no absorption of the radiation occurs in the earth's atmosphere or elsewhere, since the whole distribution of energy according to wavelength can be considered. It includes the implication that the sun behaves as a "black body"—that is, it emits the maximum amount of radiation which can be emitted at a given temperature—and to that extent the figure of 6000°K must be stated as an *effective temperature* only. (The effective temperatures of other stars range from about 3000°K to perhaps 10^5 degrees.)

However, we know as a result of Eddington's work on the equilibrium of stars that the temperature inside the sun must be much higher; the *average* temperature is thought to be about 3×10^6 degrees, and the temperature at the centre is put at about 2×10^7 degrees. The average pressure is estimated to be about 10^9 atmospheres, while the central pressure is perhaps 10^{12} atmospheres. At such temperatures ionisation of all atoms will be so complete that their average diameters are small, and the system will still behave as a more or less perfect gas (composed of ions and electrons) even at such high pressures. Now the wavelength of maximum emission at these temperatures is in the X-ray region. In the sun there must therefore be a flux of electromagnetic radiation outward, whose wavelength becomes gradually longer through successive absorption and emission until at the surface most of the emission is in the optical region. As a matter of fact, it has been a source of astonishment to astrophysicists to realise just how opaque the outer layers of the sun must be to the radiation starting from greater depths. It is thought that this is due to the rather fortunate accident that *negatively* charged hydrogen ions can exist near the sun's surface (the extra electrons coming from ionised metal atoms) which absorb visible light strongly because the rather small energies involved in this type of ionisation correspond to optical wavelengths.

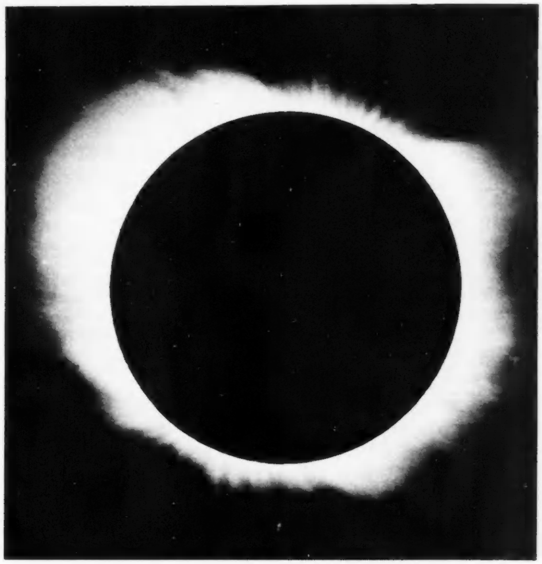

FIG. 4. The sun's corona.
(*Courtesy, Yerkes Observatory.*)

We have mentioned so far the interior of the sun, and the surface layers which are visible to us at ordinary times—the *photosphere* as it is called. As is well known, there are visible under special conditions—especially during eclipses—the flame-like projections of the *chromosphere* (these extend some thousands of miles) and also the much more tenuous *corona* (see Fig. 4) which extends to a distance at least as great as the diameter of the sun. The origin of the corona and the mechanism by which it is maintained are still matters of argument, but it is clear that its temperature is of the order of 10^6 degrees. The brilliant work of Edlén showed that the hitherto unidentified "coronium" spectroscopic lines must be due to atoms of argon, calcium, iron and nickel in a very high state of ionisation, having lost 10 to 15 electrons apiece. The temperature must therefore be correspondingly high. More recently the work of radio-astronomers has added confirmation of the estimate of temperatures; the ionised corona atmosphere is a good emitter of radio waves in spite of its low density, and it can be studied in this way at all times without interference from the photosphere. One of the most striking discoveries of radio-astronomy was indeed that the sun appeared much too hot when

viewed with "radio eyes". In the neighbourhood of sunspots and flares, in fact, radio noise may be emitted corresponding to temperatures as high as 10^{10} degrees. The only other possible explanation of these phenomena would be that *coherent* oscillations of large numbers of electrons were somehow maintained. While such oscillations can of course occur in discharge tubes they seem unlikely in stellar surroundings, and it becomes reasonable to assign a more or less real temperature in speaking of the corona.

THE HYDROGEN-HELIUM CONVERSION

Returning to the interior of the sun (which is at a temperature upward of 10^7 degrees), we see from Table I that the temperature of extensive dissociation of atomic nuclei is in the neighbourhood of 10^{10} degrees. However, at temperatures well below this, nuclear reactions will occur with significant velocity, and it is now fairly certain that the sun's energy is generated continuously by one such reaction—the conversion of hydrogen nuclei into helium. From the data of nuclear physics, it is possible to estimate the velocities of particular nuclear reactions at differing temperatures, and the question of the sun's generation of energy has excited much interest because it has appeared that the conversion of hydrogen into helium in the sun cannot be by a simple direct reaction. A detailed analysis carried out by Bethe led to the conclusion that because of the relatively narrow range of temperatures covered by the main stars the rate of generation of energy in stars must vary as a very high power of T, say the eighteenth power. This points rather firmly towards a particular process—the so-called *carbon-nitrogen cycle* —as being responsible, in the same way as a *catalyst* assists an ordinary chemical process, for the conversion of hydrogen into helium. This conversion is of course also the net result of the processes which occur in the explosion of a hydrogen bomb, but here it is carried out in quite a different way.

The data of nuclear physics make it possible also to estimate the *equilibrium* concentration of different types of atomic nuclei at a given temperature, and this leads to the question of the relative abundance of the elements on the earth, which is of such interest in cosmology. It is assumed that a young star consists mainly of hydrogen and that as its evolution proceeds more and more complex elements are built up. It seems almost certain that existing abundances on the earth are due to an origin at 10^9–10^{10} degrees and at very high density. Hoyle's well-known theory suggests that these abundances were determined at the time of the "explosion" of a *supernova* following the onset of rotational instability. The separated masses would then cool sufficiently rapidly to preserve the abundances corresponding to the temperature of the supernova.

RADIO STARS

Radio-astronomy provides very striking evidence about the high temperatures which occur in the distant heavens. Most of the radio waves received on the earth appear to originate in violent gas motions, and in the case of the strongest radio star known, which is located in the constellation of Cassiopeia, the temperature corresponding to the radio emission has been estimated as 6×10^8 degrees.

The second strongest radio star (known as Cygnus A) is thought to consist of two galaxies in collision because of its appearance as photographed at the extreme limit of resolution of the 200-inch optical telescope at Mount Palomar. First discovered by radio-astronomy, its temperature has recently been estimated as 3×10^9 degrees. The third strongest "radio star" is actually thought to be the swirling gas cloud that represents the remains of a supernova which exploded 900 years ago.

It has been realised that collisions between the gas clouds associated with galaxies should produce strong shock-waves and therefore very high temperatures, and this is thought to be the explanation for certain luminous "streamers" which have long puzzled astronomers.

The motions of gas clouds at very high temperatures must be very complex because of the high degree of ionisation. A stream of such ions or electrons constitutes an electric current which will be accelerated by a magnetic field, and will itself create a magnetic field. These effects, which come within the province of the new subject known as *magneto-hydrodynamics,* must enter into the behaviour of sunspots and flares and into the motions of these very large galactic clouds. They are also thought to play a major role in the acceleration of *cosmic rays*—our last topic in this article.

Apart from the relatively slow cosmic rays coming from the sun, the primary particles of cosmic rays consist mainly of protons and of heavier nuclei in proportions roughly according to their natural abundance on the earth. It is thought that the cosmic rays originate within our own galaxy, being kept from leaving it (just as others are prevented from entering it) by the magnetic fields associated with the gas clouds. The energies of observed cosmic rays cover at least the range 10^9–10^{17} electron-volts. Are we therefore to suppose that there exist systems within our galaxy having temperatures of, say, 10^{20} degrees? It is true that bodies of stellar dimensions (not, however, identifiable with any visible stars) have been located by radio-astronomers which emit radio waves corresponding to temperatures exceeding 10^{14} degrees. However, the prevailing idea seems to be that these exceptionally energetic particles of cosmic rays have been accelerated by moving magnetic fields within the galaxy. A suggestion put forward by Fermi in 1949 indicated how especially fast particles "injected" into a conducting gas may be accelerated further, without coming into equilibrium with the normal or "Maxwellian" distribution of energies of the other particles. Moreover, this process might be repeated many times until enormous velocities are attained.

Acknowledgments are due to Dr. W. G. Marley for Fig. 3.

THE BOOKSHELF

The Earth Beneath Us

By H. H. Swinnerton (*London, Frederick Muller, 1955, 320 pp., 30 plates, 21s.*)

In these days when contemplation of outer space and interplanetary travel is commonplace, it is refreshing to meet, and to enjoy, an authoritative review of man's progress in understanding the history of his own planet. To the laity, geologists may sometimes appear to be in the same category as those who flit in imagination from Venus to Mars, since they also talk in units of millions, not of miles but of years. However, the geologist does examine the record of the rocks, both in the field and in the laboratory, and has learnt much of the story of their making and of the earth's inhabitants at that time. It is true that there are real limitations to present-day knowledge and that the deepest borings are merely shallow pinpricks into the earth, but over the last two hundred years a great deal of knowledge has been accumulated about the earth. Much of this knowledge is summarised by Prof. Swinnerton in this book. He has had a distinguished career in both geological research and teaching and in this book he draws freely on both.

The presentation of the book is straightforward, it is divided into six parts which begin with the origin of the earth and end with the coming of man. Obviously in such a rapid survey much has had to be omitted, but this reviewer is conscious not of how much has been left out of this book but of how much has been put into it. The contents are not merely factual, but very frequently the author summarises problems of geological research and lines of interest which the layman can follow with ease. Simplicity is the keynote of presentation, and what a relief this text is from the jargon which clogs so much of scientific writing.

The first two parts contain a brief summary of many fundamental principles such as isostasy, the physical laws and geomorphological processes as well as the stratigraphical column. Also included in these first parts is a chapter which covers the more important aspects of economic geology; a minor criticism is that a diagrammatic geological section through the London Basin would help, while it would add interest to the Nottingham readers to know that the section on p. 71 is through their county. Next comes a masterly summary of the problems which confront the petrologist and economic geologist. The description of the realms of Pluto, the causes and effects of vulcanism and the variation in the nature of igneous rocks, illustrated from many areas, will provide the layman with a fascinating introduction to the subject. Granitisation, metamorphism and mineralisation are explained simply and succinctly in terms of their relationship to the broader pattern of events in the earth's history.

Passing from rocks and minerals, the author continues his description of the earth beneath us to cover variations in the earth's climate over many millions of years, and to discuss the effects of such climatic changes upon the formation of rocks of different times. The description follows a broad stratigraphical succession, from the lower palaeozoic deposits of the epicontinental seas through the Carboniferous forests and Triassic deserts to the comparatively recent Ice Ages. A significant point which the author frequently emphasises is that the climates experienced in the various parts of the world today have all been experienced at different times in this country. Ice Ages are not new climatic features since the characteristic deposits which they leave behind them prove that they have occurred from very early times.

Next Prof. Swinnerton deals with his own special fields, the procession of life and the coming of man. For those scientists whose interests lie mainly outside palaeontology, and to the layman, the presentation of such a wealth of information about the past and present inhabitants of this earth, their evolutionary trends and histories is simply explained in a delightful way. Afterwards he discusses the evolution of the vertebrates, and includes a summary of modern knowledge of man's evolution.

Here is a book which should become extremely popular, with schoolboys finding their first rocks and fossils, their parents who wish to know more about the world in which they live, and with all students of the field sciences. Finally one minor criticism, it is a pity that the excellent plates were not distributed more imaginatively. It would be much more convenient if the photographs had been placed nearer to the relevant passages in the text.

F. A. HENSON

Nuclear Species

By H. E. Huntley (*London, Macmillan, 1954, 193 pp., 21s.*)

Many introductory textbooks on nuclear physics seem to subscribe to what might be called the "stimulation" theory of teaching. After an introductory preamble (usually starting with some remark like "The enormous growth of nuclear physics since the war . . ."), they proceed to survey a more or less random collection of subjects, the primary aim apparently being to interest and stimulate the reader; this they undoubtedly do, but at the same time they leave unsatisfied the curiosity of those readers who require a more systematic approach to the facts.

Such an approach is made by Prof. Huntley. He treats nuclear physics as the study of the entire family of isotopes—natural, artificial, stable and unstable—as one group. This constitutes a background conditioning the choice of topics by the author, who constantly bears in mind the systematics of the nuclei.

After, with a short historical introduction, the author proceeds to a general discussion of isotopes and a survey of empirical rules relating mass and stability, stability of even-even nuclei, isotopic abundance, etc. This is followed by chapters on isobars, isomers, nuclear energy levels, the origin of the elements and a number of other subjects.

The chapters on nuclear energy levels give particularly clear introductory accounts of the liquid drop and shell models of the nucleus. Quite a lengthy section deals with the semi-empirical mass equation, giving a careful explanation of physical significance of its various terms, concluding with a short table showing the remarkable agreement of this theory with observation. The idea of shell structure of the nucleus is introduced by analogy with the well-known ideas of atomic structure, and it is shown how the shell model is able to account for the "magic numbers" corresponding to the nuclei of particular stability. The mathematical theory has been presented in an admirably simplified form throughout and the entire work should prove well suited for those reading for a first degree in physics.

This seems the only book of its kind, and it would seem to represent a good introduction and exposition of the subject. While it is primarily intended for Honours students in physics, it should nevertheless prove interesting and valuable to others. The book is written in a clear and simple style and contains many excellent charts and diagrams.

Physics of the Planet Mars: An Introduction to Areophysics

By Gérard de Vaucouleurs (*London, Faber, 1954, 365 pp.+10 plates, 50s.*)

Dr. de Vaucouleurs bids fair to become the world authority on conditions on Mars. In his small book *The Planet Mars*, of which the English translation was published in 1950, he gave an outline of our knowledge of the planet, its atmosphere, climate and the nature of its surface, and discussed the canals and the possibility of the existence of life. In the book under review he has produced a much more substantial work which gives full details of the physical measurements and theories on which our knowledge is based. Its scope is also extended to include a consideration of the internal constitution of the planet.

The book carefully steers clear of the question of life on Mars. The question has receded into the background of the author's field of study, and he is now only concerned to extract the utmost

information from the available observations and to form as complete a picture as possible of the conditions on the planet.

The image of the planet Mars formed, for example, at the prime focus of the Hale 200-inch telescope is less than a tenth of an inch in diameter, and all the information we have about the planet has been obtained by examining this tiny spot of illumination, magnifying it, photographing it, analysing it with spectroscope and polariscope, and measuring its variation with time. The author discusses thoroughly and painstakingly all that can be deduced from the information and gives copious literature-references both in footnotes and in a useful list at the end of the book which goes up to June 1954. No doubt there will come a time when the theories and formulae considered in this book can in some measure be applied to planets other than Mars, and it will be most useful to have all the relevant methods described in one place.

The author draws a sharp contrast between visual observation of Mars and objective physical measurement. When the speculative nature of some of the physical arguments and the lack of knowledge of the true value of the constants which appear in the formulae are realised, it becomes a matter for debate whether what one "sees with one's own eyes" is not more reliable than the data deduced by devious methods from laboriously engineered pointer readings. So impressed is the author by the apparent objectivity of the methods he describes that he has coined a new word "areophysics", the physics of the planet Mars, to describe the subject-matter of his book. It is an unhappy word and quite unnecessary. There is already the word areology meaning the scientific study of Mars as opposed to areography meaning the examination of the surface features. Anybody who pronounces the three words areology, areography and areophysics aloud in succession will understand why the last is euphonically an unsatisfactory word. It is likely to be mis-printed "aerophysics".

The book is well arranged and shows no sign that it has been translated from a French original. Each of the five parts into which the work is divided is preceded by a short statement of its purpose which will prevent the reader from losing his way amongst the numerous theories, formulae and graphs which constitute the bulk of the work. After the last part there is a summary of the conclusions to which the calculations lead, and this summary could be read with advantage both before the main work and after.

The time of publication is opportune because there will be a close approach of Mars to the earth in 1956, and Vaucouleurs appropriately finishes the text with an outline of a research programme. Any serious amateur who wishes to make useful observations of Mars should study this book. Prospective visitors to this neighbouring planet are also recommended to obtain a copy to learn what they are in for!

H. R. CALVERT

Man and the Winds

By E. Aubert de la Rue (*London, Hutchinson's Scientific and Technical Publications, 1955, 206 pp., 18s.*)

The present trend towards the development of the backward areas of the world brings an added interest in the always important subject of climatology. In spite of the efforts of national meteorological services, especially during the past few decades, much remains to be learned about the detailed climatic conditions in many parts of the world which lie off the beaten track. The author of this book makes up some of our deficiencies as far as the winds are concerned. The results of his own observations, clearly described and well illustrated by photographs, have made a fascinating book the text of which is enriched by the author's literary references. One learns, for example, of the strict regulations which have to be enforced in some parts of Switzerland to avoid dangerous fires when the *föhn*—a hot, dry and violent wind—blows, but, on the other hand, the same wind is responsible for clearing away the snow in spring. Specially interesting chapters deal with the wind's physiological effects, with sandstorms, dunes, soil erosion and other transporting effects of winds, their influence upon the location and construction of dwellings, and in agriculture, navigation and aviation.

A part of the subject which is of widespread interest is the interaction of wind and vegetation. High winds constitute an important factor in the growth of trees, and on windy hilltops there is usually little but very close grass cover, heather or very low shrubs. Where there is a strongly prevailing wind direction one finds entirely different types of climate on the opposite slopes of mountain ranges acting as wind barriers. Examples of this are found in Madagascar, New Caledonia, Fiji and in the Pacific archipelagos. On the other hand, plantations of trees are often very usefully employed as wind-breaks for the protection of crops and of dwellings, and to prevent the advance of sand dunes which prove a serious menace to agriculture in some countries.

Thus, although the wind is often regarded as man's enemy, it has its benefits and these also include the propulsion of sailing ships and the driving of windmills to both of which chapters are devoted.

The book is not highly technical, but the information it presents seems to be accurate; the work is much more than a merely entertaining account of the subject.

Miss Thompson has made a very competent translation and her notes, in amplification of the author's statements, add to the interest particularly in regard to the wind power studies which have recently been made in Britain.

Organic Reagents for Metals and Other Reagent Monographs

Edited by W. C. Johnson (*London, Hopkin & Williams, 1955, 199 pp., 15s.*)

These twenty-seven monographs by the Laboratory Staff of Hopkin & Williams Ltd. deal with some of the more important reagents.

The approach is essentially critical and practical and the monographs are arranged in alphabetical order, each with its own excellent bibliography.

The greater proportion of the reagents included give coloured complexes which are specific for the metals concerned; failing this, the interfering metals are readily eliminated by the procedures outlined. A Spekker Absorptiometer with appropriate filters is used to evaluate the coloured systems arising, and the results are then interpreted from a calibration curve produced in a similar way by using known amounts of the metal being estimated.

In an early monograph the need for careful pH and temperature regulation is underlined if highly accurate results are to be obtained.

Amounts of phenol down to 0·04 p.p.m. have been satisfactorily estimated, and, with due attention to pH and temperature, accurate estimations of zinc in the presence of substantial quantities of iron have been made by the authors over the range 0–30 μg.

The colorimetric methods of detection and estimation of metals described are primarily suited to solutions of low concentration since the aliquoting of more concentrated solutions can introduce serious errors. It is, moreover, at high dilutions that ordinary chemical methods of analysis fail.

Similar techniques are included for the estimation of amino acids and phenols. In the former case the colorimetric technique may be applied after the acids have been separated by paper chromatography. In the latter case, since the simpler phenols all form aminophenazone dyes with a μ max. of about 510 in aqueous solutions, the separation of the wanted phenol from a mixture and its subsequent estimation by these methods could be troublesome.

In some instances, e.g. the determination of copper using α-benzoin oxime, the gravimetric method is more accurate and both procedures are given.

No attempt has been made to delve into the chemistry of the coloured complexes formed, indeed, over a hundred years after Herapath's original work, the composition of one of the best known—the iron-thiocyanate complex—is still the subject of argument!

The working details for the various determinations and detections are clearly laid down and the pitfalls are pointed out as a result of a thorough

check by the authors who have included much original work.

Chemists will be glad to note that a second volume of this useful work is promised. The contents will continue some of the matter already published and will also contain monographs on additional reagents. D. S. H.

Plant Growth Regulators in Agriculture

Edited by H. B. Tukey (*New York, John Wiley, London, Chapman & Hall, 1955, 269 pp., 44s.*)

A committee of the American Society of Plant Physiologists defined plant regulators as "organic compounds, other than nutrients, which in small amounts promote, inhibit or otherwise modify any physiological process in plants", while growth regulators or growth substances "are regulators which affect growth". In the fields of knowledge covered by both the wider and narrower definitions the advances during the last decade have been almost unprecedented, and no one scientist can hope to cover a tithe of this expanding universe of new facts and fresh developments. In consequence, Dr. Tukey has assembled a team of sixteen experts to review both the fundamental and practical aspects of the use of growth regulators in both agriculture and horticulture.

The preface states that in editing the manuscripts the group of potential readers mostly in mind was the country agricultural agent who "is college trained and has a reasonably good background in both the biological and physical sciences". Even on such assumptions it is admittedly difficult to know where to start, but between sections the variation in the standards of presumed knowledge is somewhat disconcerting. In some instances, the demand on the reader is considerable, in others the very elements of botany are described.

In all there are sixteen chapters, of which the first three are concerned with the simpler principles of the physiology and chemical structure of plant regulators, while the remainder are devoted to the more practical developments with a touch or two of theory. Since the output of research and the complexity of the findings have varied greatly in different fields of investigation, the limitations of space prove more restrictive in some subjects than others. Thus, in the several chapters relating to the role of plant regulators in controlling fruit production from flowering to maturity or the effects of such compounds in promoting root growth, inhibiting sprouting or interfering with the processes of the abscission of leaves, flowers and fruits, the objective has been successfully achieved, since the front line of knowledge is delimited and the points of future advance indicated. The position in a few chapters is less satisfactory. It is not possible without over-condensation to cover within the compass of seventeen pages the yearly spate of papers which relate to weed control in field crops. On the other hand the chapter on "Plant Regulators for Weed Control in the Tropics" is conceived on a narrow basis. The emphasis is almost exclusively concerned with experiences in Hawaii and Central and South America, and there is no mention of the published work done for example between 1946 and 1952 in Mauritius, Fiji, Malaya or South Africa.

It could be well argued that since the book is aimed at the American agricultural agent, his interest will be best served by the citation of American findings. However, the appeal to a wider audience would have been heightened had it been possible to include by way of contrast and comparison more of the contributions in principle and practice made by research workers in other Continents.

G. E. BLACKMAN

FAR AND NEAR

Atomic Exhibition Touring Britain

The tour of the "Atoms for Peace" exhibition organised by the United States Information Service in co-operation with the British Atomic Energy Authority began with an opening ceremony in London at which the American Ambassador and Sir John Cockroft spoke. After ten days in London the exhibition moved to Belfast. The provisional dates for its next three stops are: Glasgow, July 7–16; Newcastle, July 22–27; Edinburgh, August 2–9. Other centres it is due to visit are Leeds, Liverpool, Manchester, Sheffield, Nottingham, Birmingham, Cardiff, Bristol and Southampton, in that order. In all, the tour will take five months.

The exhibition, which is housed in five 21-ton mobile trailers, explains vividly in terms easily understood by the layman the great possibilities for improving world living standards through international co-operation in the peaceful use of atomic energy.

With the aid of films and photographs, lighting devices, models and maps, display panels and other visual aids, facts and figures are given explaining what has already been done in the field of peaceful uses of atomic energy.

Britain's contribution to this field is amply demonstrated in the exhibition. Two prominent features are the Perspex model of Calder Hall, Cumberland, the world's first full-scale atomic power station, and a display giving statistics that show Britain's lead in exports of radio-isotopes. Great emphasis is placed on the importance of atomic power, and the range of applications of radio-isotopes—scientific, medical and industrial—are graphically indicated.

A duplicate of this exhibition is touring the Continent and has already been seen in Italy, Holland and Belgium.

Progress in Plastics

Boats and car bodies made of reinforced plastics attracted much attention at the Third British Plastics Exhibition held at Olympia last month. Two years ago when we published a note in "Progress of Science" (DISCOVERY, August 1953, pp. 234–5), the first dinghies and small sailing boats made of this material were being produced in Britain. In the interval Halmatic Ltd. of Portsmouth have produced a 45-foot cruiser with the hull of reinforced plastic moulded all in one piece. It has now become possible for motorists to place special orders for certain makes of cars with reinforced plastic bodies; for example, such bodies are available for some Ford models, while Singer and Jensen cars with plastic bodies are also to be seen on the road.

New uses for polythene were on prominent show. Courtaulds featured their polythene yarn with the trade name of "Courlene", which is commercially available in a variety of thicknesses. One fabric woven from such fibre is finding use in laboratory overalls (where it has the great advantage of being acid-resistant). A thicker fibre yields a promising upholstery fabric, whose wearing capacity is now under test in some of Coventry's buses.

* * *

T.I. Plastics Ltd. (a subsidiary of Tube Investments) has announced that it is starting research and development work on irradiated plastics and that Dr. A. Charlesby, who made pioneer discoveries at Harwell about the effect of high-energy radiation on long-chain polymers such as polythene, has joined the Tube Investments Research Laboratories, Hinxton Hall, Cambridge. The firm exhibited at Olympia some samples showing the improved heat resistance of irradiated polythene, the changes in solubility and swelling of polystyrene, the vulcanisation of rubber and silicones, and the breakdown of PTFE. (More details about these developments were recently published in DISCOVERY, April 1953, p. 153.)

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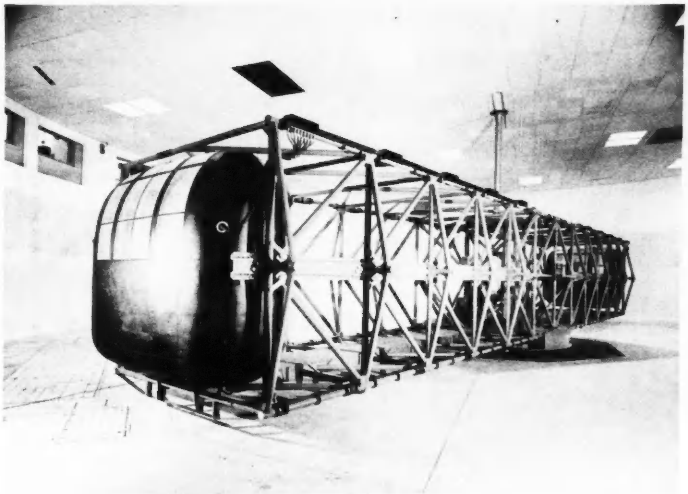
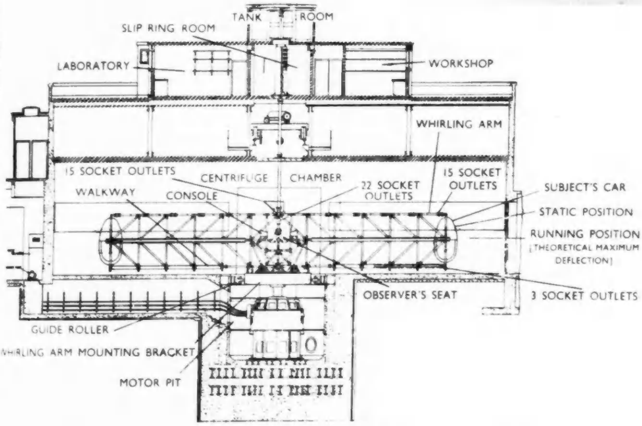
THE MAN-CARRYING CENTRIFUGE

Aviation medicine began to be concerned with "g" effects around 1929, when pilots training for the Schneider Trophy race experienced black-out due to centrifugal acceleration in turns. At 300 m.p.h. a turn of 1000 ft. radius means that the pilot meets a centrifugal force of about 6 g: that figure increases as the aircraft speed increases. Black-out (loss of vision) and loss of consciousness result because insufficient blood reaches the brain. These and other physiological consequences of too many "g" are now being investigated by the R.A.F. Institute of Aviation Medicine at Farnborough with its Man-carrying Centrifuge, which cost some £350,000.

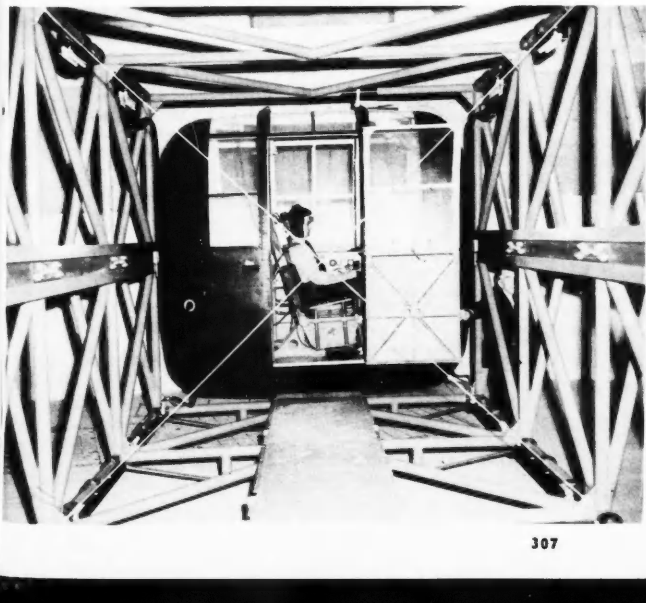




The centrifuge, shown in these photographs and sectional elevation, produces on the ground the kind of centrifugal forces a pilot may meet in combat manœuvres in a high-speed aircraft. It consists of a 60-foot rotating arm, which is spun by a 2200-horse-power motor and carries at each end a "pilot's cabin". Normally the speed of rotation is adjusted to give a maximum of 10 g in the cabin; tests can be done at 12–15 g when the pilot under test is in a prone or supine position. The pilot's reactions—pulse and respiration rates, blood pressure, and heart and brain functions are registered electrically—and recorded as graphs by either camera recorder or pen recorder.

Testing of aircraft equipment and components can be carried out at higher speeds giving forces up to 30 g.

(Below). *What happens to a subject in the "pilot's cabin". Note how the loose skin of the face is pulled downwards. Blood drains away from the eyes, and vision is blurred.*



Night Sky in July

The Moon.—Full moon occurs on July 5d 05h 28m U.T., and new moon on July 19d 11h 34m. The following conjunctions with the moon take place:

July			
18d 04h	Mercury in conjunction with the moon	Mercury	0°.1 S.
27d 19h	Saturn	Saturn	6° N.

In addition to these conjunctions with the moon, Mars is in conjunction with Jupiter on July 24d 22h, Mars 0°.6 N.; Venus is in conjunction with Pollux on July 27d 08h, Venus 6°.2 S.; Mercury is in conjunction with Pollux on July 27d 15h., Mercury 5°.8 S., and also with Venus on July 28d 01h, Mercury 0°.3 N.

The Planets.—*Mercury* rises in the early morning hours, at 3h 05m, 2h 40m and 3h 45m on July 1, 15 and 31, respectively. Its stellar magnitude varies from $-1{\cdot}6$ to $-1{\cdot}5$ and the visible portion of the illuminated disk increases from 0·173 to 0·959. *Venus* rises at 2h 45m, 3h and 3h 35m on July 1, 15 and 31, respectively. Its distances from the earth are 152 and 158 millions of miles at the beginning and end of the month, respectively; the stellar magnitude remains almost the same, changing from $-3{\cdot}3$ to $-3{\cdot}4$. *Mars* sets less than an hour after the sun on July 1 and is too close to the sun for favourable observation: at the end of the month it sets about fifteen minutes after sunset. *Jupiter* sets 1h 20m after the sun on July 1 and draws closer to the sun with which it is in conjunction soon after the end of July.

Saturn sets at 1h 05m, 0h 10m and 23h 05m on July 1, 15 and 31, respectively. Its stellar magnitude varies from 0·7 to 0·8 during this time and its distance from the earth increases from 863 to 905 millions of miles, which accounts for the small decrease in brightness.

The sun is in aphelion on July 4, reaching its maximum distance from the earth of about 94½ million miles.

The summer months are not very favourable for observing the heavens unless observers are prepared to remain up late. Amongst the summer constellations reference may be made to Hercules and especially to a wonderful star cluster in it, known as Messier 13. A very keen eye may detect it but binoculars will generally be necessary to find it. To spot it, imagine a line joining the two stars η and ζ Herculis and take a position about one-third of the distance between these two stars, this point being nearer to η; sweeping with binoculars the cluster is easily found.

Cambridge's Course in Automatic Control

Next October the Engineering Department of Cambridge University begins a post-graduate course in which instruction in the general theory of automatic control will be combined with instruction in methods of application in both industrial and military fields. Membership of the course will be open to qualified engineers and scientists who have spent two or more years in industry or a Government establishment.

Students and the Plastics Industry

In 1951 the Plastics Industry Education Fund (with an office in the Plastics Institute, The Adelphi, Adam Street, London, W.C.2) was established. In the past four years it has provided a number of bursaries (nearly all of £100 a year) for selected university undergraduates, and financial support has also been given to students at the Borough Polytechnic, Birmingham College of Technology, etc. The Fund is also financing the publication of monographs on various aspects of plastics technology. At present the Fund's net income amounts to about £3700 a year, but an appeal has now been launched with the aim of increasing that figure by two or three times. Further information can be obtained from the Education Fund's Secretary, S. P. Thompson, B.A.

* * *

The Plastics Institute publish a useful brochure called *Careers in Plastics* (which gives details about training besides career prospects in the industry), which is available to interested students, etc.

The British Nuclear Energy Conference

Because of the rapid rate of development of nuclear energy technology and the increasing demand for a common ground between scientists and engineers where these developments can be discussed, an organisation has been formed by the Institutions of Civil, Mechanical, Electrical and Chemical Engineers, and the Institute or Physics, to satisfy this need. This permanent organisation is called the British Nuclear Energy Conference, whose affairs will be managed by a Board consisting of three representatives from each of these societies. The board's chairman is Sir Christopher Hinton, and Sir John Cockcroft is a member. The secretary is Mr. Alexander McDonald (secretary of the Institution of Civil Engineers, Great George Street, London, S.W.1).

The five societies will arrange for the presentation of papers dealing with nuclear energy subjects, and all members of the societies will be able to attend and take part in the discussions.

The Conference will publish a journal about four times a year containing records of the papers, discussions, symposia and conferences conducted by the board.

The board is planning to hold its inaugural meeting in the autumn (probably November), when a symposium of lectures will be delivered on the technology of nuclear energy and its applications. It also intends to promote national and international conferences from time to time, and to arrange for British participation in international meetings.

Initially the expenses of the Conference will be met by the societies, which will make financial contributions proportionate to the size of their membership. It is anticipated that the organisation will become self-supporting once it is fully established.

A Brilliant Geological Film

Films relating to the subject of oil are among Britain's best documentaries on scientific and technical subjects; such films as *As Old as the Hills* and *Persian Story* for example reveal all the characteristics of the well-made film which is both informative and entertaining. A worthy addition to this series is the Shell film, *The Changing Earth*. In the short space of nine minutes it was obviously impossible to deal with the several processes of soil erosion in great detail, but nevertheless through first-rate photography and intelligent direction we are enabled to see something of the various means by which changes occur in the surface of the earth. The main purpose of the film, however, is to show how over a long period of geological time marine organisms are transformed into oil. The sequences which show the geological changes that bring about the deposition of oil taking place are among the best in the film. We are also shown how the techniques of geology and geophysics are utilised to identify and plot the nature and conformation of the oil-bearing rock strata. *The Changing Earth* is one of a trio of films made for the Royal Dutch Shell Group of oil companies and is the work of a brilliant young Dutch director, Bert Haanstra. The Geological and Production Department of the N.V. de Bataafsche Petroleum Maatschappij assisted in the making of the films under the supervision of Sir Arthur Elton. Two other new films—*The Search for Oil* (thirty-one minutes) and *The Wildcat* (thirty-three minutes)—are also available for free hire in both 16 mm. and 35 mm. versions from the Petroleum Films Bureau, 29 New Bond Street, London, W.1.

* * *

Many other films of scientific interest are listed in the new catalogue of the Petroleum Films Bureau. All are available on free loan to responsible organisations. Their subject-matter includes agriculture as well as petroleum refining and research, aviation and power units.

Uranium Prospecting at Blind River

The caption to the pictures of the Blind River uranium field published in our June issue (p. 236) stated that over 15,000 prospectors had staked claims there. That figure represents the total number of claims staked. Probably less than a thousand prospectors have been involved altogether.

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Classified Advertisements

OFFICIAL APPOINTMENTS

ROYAL TECHNICAL COLLEGE OF EAST AFRICA

(Principal: Major General C. Bullard, C.B., C.B.E., B.Eng., M.I.Mech.E., M.I.E.E.)

Applications are invited from candidates with good hons. degrees for the following appointments in the Department of Science:

LECTURER in CHEMISTRY, to take charge of laboratories and be responsible for development of courses. Teaching experience essential.

ASSISTANT LECTURER in PHYSICS
ASSISTANT LECTURER in BIOLOGY
ASSISTANT LECTURER in GEOLOGY

to assist in development of courses. Candidates should state any subsidiary subject they could offer. Interest in Geophysics welcomed for Geology post.

The College, established under an autonomous Governing Council by the Royal Technical College of East Africa Act, 1954, is being built in Nairobi as the main instrument in British E. Africa of higher technical and commercial education for students of all races. Teaching in Science Department will be up to inter level at first, with prospects of development to degree level, to which candidates must be able to teach.

Salary scales (including temporary c.o.l.a)—Lecturers £1162–£1637 p.a.; Assistant Lecturers £937–£1241 p.a., or slightly lower for transferred staff wishing to retain Col. Govt. pension rights (staff on scales quoted could contribute to College pensions scheme or maintain existing rights under, e.g. F.S.S.U. or Ministry of Education, College paying employer's contributions). Starting salaries according to qualifications and experience. Partly furnished houses or flats provided, rent according to salary . Free 1st class passages to and from Kenya on first appointment, leave and normal retirement for persons appointed and wives: up to equivalent of one adult passage for dependent children under twenty-one. Leave on full salary at rate of four days for each month's resident service. Tours of service 24–36 months.

Write for further information to Secretary, Advisory Committee on Colonial Colleges, 1 Gordon Square, London, W.C.1. Closing date for applications (6 copies) 11th July 1955.

ASSISTANTS (SCIENTIFIC): The Civil Service Commissioners invite applications for pensionable posts. Applications may be accepted up to December 31, 1955, but early application is advised as an earlier closing date may be announced either for the competition as a whole or in one or more subjects.

Interview Boards will sit at frequent intervals.

Age at least 17½ and under 26 years of age on January 1, 1955, with extension for regular service in H.M. Forces, but candidates over 26 with specialised experience may be admitted.

Candidates must produce evidence of having reached a prescribed standard of education, particularly in a science or mathematical subject. At least two years' experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces essential in one of the following groups of scientific subjects:

(i) Engineering and physical sciences.
(ii) Chemistry, bio-chemistry and metallurgy.
(iii) Biological sciences.
(iv) General (including geology, meteorology, general work ranging over two or more groups (i) to (iii) and highly skilled work in laboratory crafts such as glass-blowing).

Inclusive salary scale £262 (at 18) to £545 (men) or £469 (women). Starting pay up to £402 (men) or £362 (women) at 25. Women's pay subject to improvement under Equal Pay Scheme. Somewhat less in provinces. Opportunities for promotion.

Further particulars from Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting No. S.59/55.

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY require a CHEMICAL ENGINEER to act as TECHNICAL CONTROL OFFICER at the Industrial Group Headquarters, Risley, Nr. Warrington, Lancs., to be responsible to a Senior Technical Control Officer for the headquarters co-ordination of nuclear operations associated with the Group's chemical plants. Duties will involve collaboration in the development work on existing plants and its integration with future schemes arising from research, the determination of optimum operating methods and levels, target flow sheeting, costing and raw material utilisation.

Candidates must have an honours degree in engineering, chemical engineering, or chemistry, Corporate Membership of the Institution of Chemical Engineers or equivalent. Experience of the operation and development of conventional chemical plants essential, and some knowledge of radio-chemical plant practices is desirable.

Salary £1700–£2200 p.a. (male). All new entrants under the age of 55 automatically join the Authority's pension scheme. A house will be available within a reasonable period for the successful candidate if married. Send postcard for application form to the UNITED KINGDOM ATOMIC ENERGY AUTHORITY, Industrial Group Headquarters, Risley, Nr. Warrington. *Ref. 973 must be quoted.*

TRAINING OFFICER required by the UNITED KINGDOM ATOMIC ENERGY AUTHORITY at CAPENHURST, NR. CHESTER, to be responsible to the Training Manager in a large industrial organisation for devising and implementing training programmes covering staff and industrial employees. Main duties will be the supervision of a craft apprenticeship scheme and the organising and conducting of junior supervisory courses. Applicants should have served a recognised engineering apprenticeship and should have Corporate Membership of a Senior Engineering Institution or equivalent. Three years' experience in a works is essential. Experience in teaching or lecturing desirable. Salary £695 (at age 25) to £1065 p.a. All new entrants under the age of 55 automatically join the Authority's Pension Scheme. Send postcard for application form to the UNITED KINGDOM ATOMIC ENERGY AUTHORITY, Industrial Group Headquarters, Risley, Nr. Warrington. *Ref. 978 must be quoted.*

TECHNICAL EDITOR required by Research and Development Branch of the UNITED KINGDOM ATOMIC ENERGY AUTHORITY at CAPENHURST, near Chester, to assist scientific staff of a large development laboratory in the preparation of technical reports. These reports convey information to Research, Design and Works Operation staff of the Atomic Energy Authority, and important action is based on the information. The technical Editor will be responsible for the logical presentation of the arguments of the reports and for the clear presentation of conclusions and recommendations. Applicants must have a good command of the English language and must be aware of the problems involved in communicating information. A first or second class honours degree in an arts or science subject is desirable, and an appreciation of technical problems, and training in some branch of science or technology, would be an advantage. Salary £1090–£1285 p.a. All new entrants under the age of 55 automatically join the Authority's contributory pension scheme. Applications to UNITED KINGDOM ATOMIC ENERGY AUTHORITY, Industrial Group Headquarters, Risley, near Warrington. *Ref. 994 must be quoted.*

APPOINTMENTS VACANT

MICRO-ANALYST

COURTAULDS LIMITED has a vacancy in its new Viscose Research Laboratory, Coventry, for an Analyst, with experience of micro-techniques. This is a new and important appointment for a man who can work by himself and develop new techniques.

Candidates should apply for a detailed form of application to the Director of Personnel, Courtaulds Limited, 16 St. Martin's-le-Grand, London, E.C.1, quoting the reference number D.66.

THE ELECTRICAL RESEARCH ASSOCIATION

invite applications from graduates in Physics for appointments in connexion with fundamental investigations on the thermal behaviour of buildings, the storage of electrical energy as heat, and thermodynamic problems in new applications such as the heat pump and the use of solar energy.

Positions are available for young graduates as well as for those with post-graduate training and experience. Salaries are based on experience and qualifications and permanent employment comes within the F.S.S.U. Applications to be made to the Director, E.R.A. Laboratories, 5 Wadsworth Road, Greenford, Middlesex.

FORD MOTOR COMPANY LIMITED

DAGENHAM, ESSEX

require a

LENS DESIGNER

Applications are invited from Designers—not necessarily in the Motor Industry—with experience in photometrics, tests, materials, finishes, etc., who are prepared to adapt their experience to Motor Vehicle Lighting.

The position, which is permanent and pensionable (non-contributory superannuation scheme), is a responsible one and a salary commensurate with such responsibilities will be offered.

Early consideration will be given to applications, which should contain brief details of experience and quote ref. VCL/3, and be addressed to the Salaried Personnel Department.

Continued overleaf

FAR AND NEAR—*continued*

Meteorological Office Inquiry

A Government committee has been appointed under the chairmanship of LORD BRABAZON to review the organisation of the Meteorological Office in relation to present and future requirements. Other members of the committee are SIR CHARLES DARWIN, F.R.S., MAJOR R. H. THORNTON, SIR FOLLIOTT SANDFORD and MR. J. R. SIMPSON.

Bart's 15 MeV Linear Accelerator

Britain's most popular linear accelerator designed for radiotherapy is now installed in the medical college of St. Bartholomew's Hospital, London. At an official ceremony on April 27 the Duke of Gloucester set this 15 MeV instrument working.

For the next two years the accelerator will be used almost entirely for radiobiological research. During this period experiments will also be made with the aim of developing two new methods of radiotherapy, one using fast electrons, and the other using neutrons which can also be produced in large quantities in the accelerator. (Neutrons are thought to have interesting possibilities: in the U.S.A., for instance, they have been used to produce intense local irradiation of brain tumours, the technique depending on a localised concentration of boron which is then subjected to a beam of slow neutrons.)

The instrument produces X-rays at a very high intensity; the X-ray output can be as high as 3000 roentgens per minute at a distance of 1 metre, many times higher than that with any other radiotherapy machine. The radiations are emitted from the machine in a series of short pulses, each lasting about a millionth of a second. Within each burst the intensity of radiation is extremely high, as much as 15,000 roentgens can be delivered in a little over a millionth of a second. This means that one can observe the effects delivered by the radiations within an exceedingly short time, a feature that makes it possible to study the mechanism by which a living cell is destroyed by the passage of radiations through it. The machine incorporates a new device for terminating exposures after a predetermined number of pulses have been produced. (Details can be found in Prof. J. Rotblat's article on this accelerator in *Nature*, vol. 175, pp. 745–7.)

London Airport's New Radar Installation

The equipment of the new control tower of London Airport which has just come into operation includes the world's first "Q" Band Airfield Surface Movement Indicator. This radar installation operates on the very high frequency of approximately 34,000 megacycles in the relatively unexplored 8 mm. "Q" Band, and gives a picture of the airport that defines the runways and taxiways with photographic precision, and provides precise information at short range of the movement of aircraft on the ground, vehicles and even pedestrians. Thus the control staff will be able to supervise airfield surface movements accurately and rapidly, particularly under conditions of poor visibility.

New Laboratory Glassware

Quickfit & Quartz, Ltd., the manufacturers of scientific and industrial glassware, introduced a number of important additions to their standard range, at an exhibition held in April at the Imperial College of Science and Technology.

Among the exhibits were the following new pieces of apparatus:

Circulatory Cyclone Evaporator. This steam-heated apparatus will evaporate aqueous solutions at a rate in excess of 5 litres per hour under the vacuum of a water pump. Its main advantage is continuous rapid evaporation with a small working volume (approximately 500 ml.). It is suitable for heat-sensitive materials.

Climbing Film Evaporator. This is capable of evaporating aqueous feed stock at the rate of 3 litres per hour when under vacuum, so that water boils at approximately 40°C. A typical use is concentration of heat-sensitive materials (e.g. fruit-juice, milk).

Semi-micro Molecular Still. In this the liquid to be fractionated is allowed to run slowly down a platinum or nickel spiral closely fitting inside the glass tubular body of the still. The outside of this is heated electrically by a jacket, the temperature of which is carefully controlled so that the most volatile compound is separated from the remaining liquid. Condensation takes place on a water-cooled condenser tube, which forms the axis of the spiral. On completion of the run, the still is turned through 180° on the spherical joint fitted to the vacuum lead and the process repeated as many times as is necessary to obtain the required fractions.

Non-return Valve. To overcome the difficulty of water sucking back from a pump into a filter funnel, or apparatus under vacuum, a small but effective non-return valve has been produced. The novel design allows complete dismantling so that thorough cleaning is easy.

Chromatocoil. A compact piece of apparatus for one-dimensional paper strip chromatography. Although it measures only 5 inches by 4 inches by 3 inches overall, it accommodates two strips, 50 cm. by 1 cm. Thus several units can readily be put in a refrigerator or incubator if necessary, so that the separation may be run above or below room temperatures.

Full particulars of all the new additions to their standard range are given in the firm's special supplement to their catalogue due for publication this month. Interested readers should write to Quickfit & Quartz, Ltd., Heart of Stone, Stone, Staffs.

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